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SUPPORTING NEW HORIZONS: THE EVOLUTION OF THE MILITARY SATELLITE COMMAND AND CONTROL SYSTEM, 1944-1969

David Christopher Arnold, Major, USAF

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DISSERTATION ABSTRACT

SUPPORTING NEW HORIZONS: THE EVOLUTION OF THE MILITARY SATELLITE COMMAND AND CONTROL SYSTEM, 1944-1969

David Christopher Arnold

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(B.A., Purdue University, 1989)

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Directed by James R. Hansen

Like every large technological system, military or civilian, the Air Force Satellite Control Facility evolved because of the interaction of human beings with technology. The Air Force Satellite Control Facility did not simply turn out the way it did because the technology evolved autonomously. The United States Air Force purposefully built the Air Force Satellite Control Facility to support the National Reconnaissance Program. In his large body of writing, historian Thomas Parke Hughes has shown that large technological systems evolve as social constructions according to a pattern of systems development. The Air Force Satellite Control Facility grew in the early 1960s into a true satellite command and control network following this Hughesian pattern of development. The air force system of satellite command and control, therefore, provides an example of how a large technological system, designed not for the marketplace but for government needs, still evolved as a socially constructed technology. The Air Force Satellite Control Facility illustrates a pattern of systems development that applies whether the system is a

large private venture like an electrical power network or an important government project like a satellite command and control system.

In the case of the Air Force Satellite Control Facility, however, there was an extraordinary player in the background pulling strings. The Air Force Satellite Control Facility had a unique relationship with the National Reconnaissance Office, a secret organization that the government officially concealed into the 1990s. In the special relationship between the National Reconnaissance Office and the Air Force Satellite Control Facility, one sees a social construction of technology at the behest of a particular interest group most clearly revealed. Therefore, this dissertation will show the Air Force Satellite Control Facility evolved as a social construction, according to the Hughes model, solely to support satellite-based reconnaissance.

BIBLIOGRAPHIC ESSAY

In August 2000, my house became a satellite tracking station. Sears sold an eighteen-inch satellite dish in a box, and a subcontractor (of course) stuck it up on the side of the house. Then, to paraphrase Bruce Springsteen, the television had 157 channels and nothing on. That eighteen-inch dish turned the house, for less than $200, into a passive tracking station for a geostationary communications satellite, while each remote tracking station in the Air Force Satellite Control Facility cost the American taxpayer millions (although they certainly had many more capabilities and sophistication than my small dish). The new eighteen-inch system could do nothing more than receive, but it was capable of something that even nation-states could not accomplish two generations ago. The transformation that has occurred in two generations deserves study.

Two books that are contemporary with the initial development of satellite command and control are Shirley Thomas's *Satellite Tracking Facilities* and Eloise Engle and Kenneth Drummond's *Sky Rangers*.[1] The author rescued these books from certain oblivion in the discard piles of local libraries, one in Farmington, Utah, and another in Columbus, Georgia. When these books were published in the early 1960s, space was new and exciting and anything associated with it probably launched off bookshelves.

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[1] Shirley Thomas, *Satellite Tracking Facilities: Their History and Operation* (New York: Holt, Reinehart and Winston, 1963); and Eloise Engle and Kenneth Drummond, *Sky Rangers: Satellite Tracking Around the World* (New York: The John Day Company, 1965).

These two books, however, are little more than surveys of the various technologies available at the time to track satellites, superficially covering a wide variety of topics from NASA's Minitrack network to the navy's space surveillance network. Because at the time "to track" a satellite meant command and control as much as it meant watching an object cross the sky, these two books are just as devoted to radio tracking as they are to visual observation of satellites. They are the last books exclusively devoted to satellite tracking until the twenty-first century.

NASA official histories have had little to say about the ground networks that made it possible for controllers to be in touch with astronauts or to monitor their own satellite programs. The official history of the Vanguard program,[2] the nation's first civilian satellite project, talks about its network of tracking stations, Minitrack, in some detail. Because Minitrack was a network planned for one satellite program, it accomplished very little after "Kaputnik," a nickname for the 6 December 1957 failure of the Naval Research Laboratory's first attempt to leave the launch pad. Minitrack's long-term significance rests in its inclusion into NASA's many and varied manned and unmanned programs. In the official history of the piloted Mercury program, *This New Ocean*, there is some discussion of the tracking network, but mostly as it relates to the obsession of flight surgeons for constant contact with the astronauts during all phases of spaceflight. But according to the authors, the full extent of the tracking range and communications network was beyond the scope of their 681-page volume.[3] By the time one finally reaches the Gemini and Apollo programs, other technologies and factors play

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[2] Green and Lomask, *Vanguard: A History.*

[3] Swenson, et al., *This New Ocean*, pp. 214-15.

such an important role that the ground segment of these programs, largely built for Mercury and kept on into Gemini and Apollo, blend into the background.

Douglas Mudgway's history of NASA's own satellite command and control network, called the Deep Space Network, corrected some of the omissions of previous NASA histories. *Uplink/Downlink*, however, is an internalist history of a technology, doing little to enhance our understanding of the social construction of large technological systems. A typical "nuts and bolts" look at the way NASA developed its satellite command and control methods, in fact, continues the myth that the history of technology is about artifacts, not about the people who created them.[4]

An official NASA publication that does not ignore the history and development of NASA's ground network is James R. Hansen's story of the Langley Research Center,

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[4] Douglas J. Mudgway, *Uplink/Downlink: A History of the Deep Space Network*, NASA SP-2002-4225 (Washington, DC: Government Printing Office, 2002). Also needed, though, is a history of the ARIA aircraft, which were essentially flying tracking stations that NASA first used for the Apollo program, but which the air force recently retired because of cost (upwards of $100,000 an hour to fly), replacing them with the NKC-135B Big Crow. ARIA was an acronym for Apollo Range Instrumentation Aircraft, developed in 1968 to receive, record, and retransmit telemetry data and voice communications between astronauts and the Houston Control Center. Later known as the Advanced Range Instrumentation Aircraft, the ARIA fleet consisted of eight highly modified EC-135 and EC-18B/D aircraft maintained by the Air Force Material Command's 452d Flight Test Squadron. ARIA aircraft served as airborne tracking stations often over water when ground tracking stations were out of range of a satellite's mission profile. A recent success came in 1996 when NASA used an ARIA aircraft to help the Mars Global Surveyor reach its planned trajectory by sending data through an antenna at the Diego Garcia Tracking Station, into the Air Force Satellite Control Network data stream, and out to NASA's Goddard Space Flight Center. http://www.edwards.af.mil/aria, accessed 11 Jan. 2000; Leigh Anne Bierstine, "ARIA makes final touchdown at Edwards," 27 Aug. 2001, http://www.af.mil/news/Aug2001/n20010827_1185.shtml, accessed 27 Aug. 2001.

Spaceflight Revolution.[5] Hansen nicely fits the development of the tracking station networks into Langley's (and NASA's) overall story. This work includes anecdotes about survey trips, including a story about a team that set down in the Congo in 1966 to do a survey for a Mercury tracking station, and found themselves in the middle of the first Congolese Revolution.

Official United States Air Force publications, of which there are many volumes of organizational history, say even less about satellite command and control. In fact, nothing, save three pages in David N. Spires's official air force in space history, *Beyond Horizons*, has been written about the men and women on the ground and the equipment that they used to make the space programs of the United States possible.[6] Their contributions have remained in the background, until now, even though the Air Force Satellite Control Facility was and is an indispensable and dynamic organization that underwent many evolutionary changes on its way to becoming the first common-user network for space command and control.

Although there is a wide variety of information available on satellite command and control, it is often hard to find because archivists have buried it in other topical collections. Further, the documents that deal with satellite command and control also deal with a variety of other details regarding myriad satellite programs. Once the Air Force Satellite Control Facility became an independent organization and began recording

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[5] James R. Hansen, *Spaceflight Revolution: NASA Langley Research Center from Sputnik to Apollo*, NASA SP-4308 (Washington, DC: Government Printing Office, 1995), p. 67.

[6] Spires, *Beyond Horizons*, pp. 167-169.

its own official histories, more administrative details became available but even fewer technological details.

In the hope of sparing future researchers the frustrations of dead ends and false starts, this essay contains information not usually found in bibliographies. Where applicable, I have included either the depository where the documents can be found or the other details necessary for tracking them down. Already having a defense department security clearance because of my status as an air force officer on active duty speeded up the process for requesting declassification review, but rest assured, the documents are there, waiting for civilian historians to mine them.

The largest collection of documents on the administrative history of the Air Force Satellite Control Facility lies in a vault near Colorado Springs, at the Air Force Space Command Headquarters History Office (AFSPC/HO) on Peterson Air Force Base. AFSPC/HO's historians, while overworked, understaffed, and with a critical shortage of office space, took valuable time to help me find what I needed. There are boxes and boxes and reams and reams of official documents and photographs on the history of the Air Force Satellite Control Facility, most of which unfortunately--and unnecessarily--remain classified. The nature of the collection is such that it is unique and literally unduplicated anywhere in the air force. Researchers should beware that special arrangements need to be made for viewing and using the collection because of its classified status, the nature of the history office as a functioning official military unit, and the complete lack of space for researchers in the history offices.

An equally valuable repository that is set up to handle researchers is the Air Force Historical Research Agency (AFHRA) at Maxwell Air Force Base, in Montgomery,

Alabama. AFHRA's sole mission is to help researchers in and out of the air force write history. The collection is open to the public and the archivists bend over backwards to help, pleased to have people look at their collections. Their collections run the gamut from oral histories and official histories to special studies, technical documents, and personal papers.

An equally valuable collection, but still difficult to use, is the National Reconnaissance Office (NRO) in Chantilly, Virginia. Their collection of declassified and redacted documents from the previously classified CORONA, ARGON, and LANYARD satellite programs is helpful, but focuses almost entirely on the development of the satellites themselves, not the system of command and control that made them useful for national security. Further, NRO's obsession with security requires advance planning for the researcher and the understanding that a lot of details are available elsewhere but redacted here.

The hardest nut to crack was the Defense Technical Information Center (DTIC), a repository of every technical report written under defense department contract and a great source of developmental details on satellite command and control, but closed for most significant details to most non-defense department users. Many documents in DTIC's collection on the CORONA satellite program's Subsystem H remain unnecessarily classified. Although searchable on-line, DTIC does not have a reading room and is set up to support the needs of the defense community, not historical researchers. If you are interested in exploring the technology of satellite command and control in much greater detail, including down to the box level, or if you enjoy wiring diagrams and

organizational charts, then this is definitely a place you must visit on-line at http://www.dtic.mil.

By far the most valuable resource for this dissertation has been the personal insights of the people who were there when it all happened. Until the declassification of the CORONA program in the 1990s, many of the pioneers of the American military's space program *could* not and *did* not talk about their experiences. Because of this, many of the recorded official histories do not contain references to the early satellite programs. In addition, many of these people could not write anything down during their tenures and so much of the evidence remains oral history, sometimes tainted by fading memories and personal embellishments. Historians do not often have the opportunity to talk to the original participants, but historians of space history and other recent history topics, certainly should not pass up this opportunity to meet the pioneers of their field of research. The author has been privileged and honored to meet some of them and to talk with others on the telephone. In addition, using electronic mail the author has met and talked with others who have provided incredible details that were not written down anywhere until now.

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SUPPORTING NEW HORIZONS: THE EVOLUTION OF THE MILITARY

SATELLITE COMMAND AND CONTROL SYSTEM, 1944-1969

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee.

David Christopher Arnold

William F. Trimble Professor History	James R. Hansen, Chair Professor History
Robert J. Jakeman Associate Professor History	Stephen L. McFarland Acting Dean Graduate School

SUPPORTING NEW HORIZONS: THE EVOLUTION OF THE MILITARY SATELLITE COMMAND AND CONTROL SYSTEM, 1944-1969

David Christopher Arnold

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David Christopher Arnold

Signature of Author

Date

Copy sent to:

Name	Date

DISSERTATION ABSTRACT

SUPPORTING NEW HORIZONS: THE EVOLUTION OF THE MILITARY SATELLITE COMMAND AND CONTROL SYSTEM, 1944-1969

David Christopher Arnold

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Like every large technological system, military or civilian, the Air Force Satellite Control Facility evolved because of the interaction of human beings with technology. The Air Force Satellite Control Facility did not simply turn out the way it did because the technology evolved autonomously. The United States Air Force purposefully built the Air Force Satellite Control Facility to support the National Reconnaissance Program. In his large body of writing, historian Thomas Parke Hughes has shown that large technological systems evolve as social constructions according to a pattern of systems development. The Air Force Satellite Control Facility grew in the early 1960s into a true satellite command and control network following this Hughesian pattern of development.

The air force system of satellite command and control, therefore, provides an example of how a large technological system, designed not for the marketplace but for government needs, still evolved as a socially constructed technology. The Air Force Satellite Control Facility illustrates a pattern of systems development that applies whether the system is a large private venture like an electrical power network or an important government project like a satellite command and control system.

In the case of the Air Force Satellite Control Facility, however, there was an extraordinary player in the background pulling strings. The Air Force Satellite Control Facility had a unique relationship with the National Reconnaissance Office, a secret organization that the government officially concealed into the 1990s. In the special relationship between the National Reconnaissance Office and the Air Force Satellite Control Facility, one sees a social construction of technology at the behest of a particular interest group most clearly revealed. Therefore, this dissertation will show the Air Force Satellite Control Facility evolved as a social construction, according to the Hughes model, solely to support satellite-based reconnaissance.

Style manual used: The Chicago Manual of Style, 14th ed (Chicago: University of Chicago Press, 1993).

Computer software used: Microsoft Word 2000.

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INTRODUCTION

"GOLDSTONE HAS THE BIRD!"

> [He] came up and shoved a piece of paper in my hands, on which were these magic words: *Goldstone has the bird!* . . . Then someone turned up the loudspeaker, and we heard the President announcing that the United States had successfully launched an earth satellite.[1]
>
> -- Maj. Gen. John Bruce Medaris
> Commander, Army Ballistic Missile Agency

Societies orbit artificial satellites to collect data. Today, satellites perform a variety of data-related tasks: science, reconnaissance, navigation, weather observation, and communications. To accomplish long-distance relay of data, engineers and scientists use telemetry. Satellite telemetry tells the amount of control gas on board a satellite, or the voltage in its batteries; it can reveal the temperatures of certain critical parts, or when the engine starts or stops. Telemetry can measure anything measurable. Telemetry may also include mission-data, such as pictures of far-away lands, or telephone calls, or navigation signals.

The long and varied origins of space telemetry reach deep into the nineteenth century when wire links preceded modern radio methods of transmission. As early as 1845, the Imperial Russian army developed a "telemeter" for recording the speed of flight

[1] John B. Medaris, *Countdown for Decision* (New York: G.P. Putnam's Sons, 1960), 222-5. Emphasis in the original. In reality, the Goldstone antennas were not operational until the next year, but the information was correct: Explorer I did successfully achieve orbit, the first American satellite to do so, and eventually proved the existence of the van Allen radiation belts around the Earth.

of cannonballs. American O. J. Bliss brought telemetry from the lab to industry in the 1912 *Transactions of the American Institute of Electrical Engineers*. In his paper, Bliss described how to use telemetry to transmit information about the generation of electrical power. Not until World War II did telemetry and radio marry in missile development, a union that has proven fruitful and long lasting.[2]

"Satellite command and control" provides the essential link between the satellite in its lonely orbit and the people who need its data. Regardless of the mission, satellites gather data, sending it back to earth using radio signals, where humans interpret it. Space vehicles need human interaction to make sure they function correctly and to tell them what to do or what not to do. Because of the nature of satellites, their missions, and their orbits, a satellite requires human intervention at many points in its existence for "support." Radio connections between the spacecraft and the ground are necessary for retrieving the data. A satellite may transmit data obtained from its sensors, data regarding systems status, or responses to queries sent from the ground. If there is no one there to receive and interpret its transmissions, however, the data are lost, and so might be the satellite. An earth station can send data, receive data, give commands (such as transfer to a redundant system or fire a thruster), determine satellite orbit, or ask the vehicle questions about its systems. This act of sending and receiving information between a satellite and a ground station is the essence of satellite command and control.

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[2] *Journal Ministère Russie Defense* 47, Section 7 (1845): 25, and O. J. Bliss, "Electrical Transmission of Electrical Measurements," *Transactions of the American Institute of Electrical Engineers* 31 (1912): 1537-40, both in Wilfrid J. Mayo-Wells, "The Origins of Space Telemetry," *Technology and Culture* 4 (Oct. 1963): 500-1.

Communications, command, and control, as well as the satellites themselves, are the basic elements of a space-based data-collection system.[3]

Radio signals used to transfer data are line-of-sight so a remote tracking station (RTS) can control and obtain data from a satellite only while the satellite is within sight of a huge ground antenna. For low-orbiting satellites, line-of-sight periods are limited, sometimes as brief as five minutes. Consequently, RTSs must be widely scattered, yet also linked to a central control center. For example, as he flew over Australia, Mercury astronaut John Glenn could tell controllers on the ground that he saw the lights of Perth because the National Aeronautics and Space Administration (NASA) had a ground station in the western part of the continent.[4]

Satellite command and control is a tricky and complicated task, as difficult as any other aspect of satellite operations, and just as important. Imagine trying to find a vehicle the size of a school bus twenty-three thousand miles from a point on the other side of the globe without knowing precisely where it is or what radio frequency to use to talk to it. Alternatively, imagine an airplane flying overhead at the speed of sound. If the pilot ejects an object the size of a golf ball at sixty thousand feet, the apparent size and speed of the golf ball will be approximately that of a three-foot satellite at three hundred miles.[5]

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[3] Aerospace Corporation, *The Aerospace Corporation: Its Work, 1960-1980* (El Segundo, CA: Aerospace Corp, 1980), 123.

[4] Loyd S. Swenson, Jr., James M. Greenwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury*, NASA SP-4201 (Washington, DC: Government Printing Office, 1966), 428.

[5] Dr. John T. Mengel, March 1956, quoted in Constance McLaughlin Green and Milton Lomask, *Vanguard: A History*, NASA SP-4202 (Washington, DC: Government Printing Office, 1970), 147.

Now find the "satellite" against the background of space, in less than five minutes, and communicate with it, otherwise it might be lost forever. Such is the business of the ground network of space command and control. Today, in support of its own and other agency's satellites, the United States Air Force performs this vitally important mission twenty-four hours a day, seven days a week, fifty-two weeks a year, at an accuracy rate of nearly one hundred percent.[6] In the beginning, however, satellite command and control was not always so reliable and the air force performed satellite command and control for one agency, the National Reconnaissance Office (NRO), the nation's operators of reconnaissance satellites critical for the opening up of the USSR in the tense days of the Cold War.

For years, the emphasis in airplane programs had been on complete systems, including the ground equipment. In the late 1950s and early 1960s, the air force continued the policy of acquiring a complete system with its development of the Advanced Reconnaissance System, which the Air Research and Development Command (ARDC) called Weapon System 117L (WS-117L). The reconnaissance satellite program office called the ground network for command and control simply "Subsystem H" because, when first planning for the first space launches in the 1950s, the managers and engineers working for the air force already understood the need for a complete space system.

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[6] 1991 statistics: 113,000 individual satellite contacts, achieving a mission success rate of better than 99.85 percent in satellite acquisition, commanding, tracking and telemetry, and network data communications. "The AFSCN History," http://www.safaq.hq.af.mil/aqsl/afscn/history/history.html, accessed 28 Jan. 2000.

During the mid-1950s, the Western Development Division of ARDC funded WS-117L under prime contractor Lockheed Aircraft Corporation. Famous for its World War II fighters, Lockheed had never before taken on a space-related project. Seeing an opportunity, the aircraft manufacturer based its satellite proposal on the use of a booster missile already in production and on a new upper stage called Agena to orbit payloads for a number of applications, principally reconnaissance of the Soviet landmass. United States Air Force Col. Frederic C. E. Oder, head of the WS-117L weapon system program office in Los Angeles, intended the program to demonstrate that the United States "could launch, control, get information from, program, and position a space craft."[7] The program did much more than that, providing intelligence for the United States for the next two decades.

From the beginning, the air force intended to make satellite command and control a military operation. In April 1959, the service dedicated a unit to providing satellite tracking support, the 6594th Test Wing (Satellite), with three operating locations at Edwards Air Force Base (AFB), California; Chiniak, Alaska; and Annette Island, Alaska.[8] In late 1959, the air force added the tracking stations at Vandenberg AFB,

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[7] Frederic C. E. Oder, USAF, Retired, interview by Herb Zolot, Colorado Springs, Colo., tape recording, 1993, Air Force Space Command History Office, Peterson AFB, CO (hereafter AFSPC/HO).

[8] A brief note about organizational names. The air force organization responsible for satellite command and control has been through a series of names in its history. For consistency, this dissertation uses "Air Force Satellite Control Facility" to mean that military organization providing satellite command and control services to agencies of the defense department.

California; New Boston Air Force Station, New Hampshire; and Kaena Point, Hawaii.[9] Together the operating locations and tracking stations made up the Air Force Satellite Control Facility (AFSCF). These tracking stations and their command center in Sunnyvale, California, stand at the center of the story of the evolution of the military's system of satellite command and control.

Unfortunately, historians have obscured the importance of ground tracking stations to the American space program--civilian and military--even though they have written a large number of articles and books about American satellite programs.[10] Authors show fascination with the missiles and the management styles that put the satellites in orbit, but ignored the tracking stations that keep the satellites useful while in orbit.[11] Some historians have written about the air force contribution to space

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[9] MSgt Roger A. Jernigan, *AFSCF Historical Brief and Chronology* (Sunnyvale, CA: Air Force Satellite Control Facility History Office, 1983), 19-20.

[10] See William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Random House, 1986); Dwayne A. Day, et al., *Eye in the Sky: The Story of the CORONA Satellites* (Washington, DC: Smithsonian Institution Press, 1998); Curtis N. Peebles, *The CORONA Project: America's First Spy Satellites* (Annapolis, MD: Naval Institute Press, 1997); and Jeffery T. Richelson, *America's Secret Eyes in Space: The U.S. Keyhole Spy Satellite System* (New York: Harper and Row Publishers, 1990).

[11] See John Lonnquest, "The Face of Atlas: General Bernard Schriever and the Development of the Atlas Intercontinental Ballistic Missile, 1953-1960" (Ph.D. diss., Duke University, 1996); Jacob Neufeld, *Ballistic Missiles in the United States Air Force, 1945-1960* (Washington, DC: Government Printing Office, 1990); Thomas Parke Hughes, *Rescuing Prometheus* (New York: Pantheon Books, 1998); Stephen B. Johnson, "Samuel Phillips and the Taming of Apollo," *Technology and Culture* 42 (Oct. 2001): 685-709; and Stephen B. Johnson, "Bernard Schriever and the Scientific Vision," *Air Power History* 49 (spring 2002): 30-45.

surveillance and missile warning,[12] but little about the equally vital mission, satellite command and control. This study attempts to fill in part of that void in space history.

Although historians have neglected satellite command and control, since 1945 scientists and engineers have understood the need for an integral network of ground stations for space operations. Without the ground segment, there would have been no verifiable space "firsts" like Explorer I achieving orbit in 1958, prompting Maj. Gen. Bruce Medaris to proclaim, "Goldstone has the bird!" Just as challenges faced the earliest developers of rockets and space vehicles, management and technological challenges have been part of the history of military satellite command and control. Although developed haphazardly, the air force's satellite control network has been as vital to national defense as any satellite program, perhaps more so because it supports so many different satellite programs. In short, without the military satellite command and control system, there could have been no winning the Cold War.

Before the end of World War II, Dr. Theodore von Kármán and other well-known American scientists produced *Toward New Horizons*, a report on their vision for the future of American air forces. From this report soared an air force wedded to technology. Gen. Henry H. Arnold, chief of United States Army Air Forces, already looked at the war as won and at the air force as a separate military service. Arnold wanted the aviation service to be prepared to fight the next war, which he assumed would be a technological

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[12] See Desmond Ball, *Pine Gap: Australia and the U.S. Geostationary Signals Intelligence Satellite Program* (Boston: Allen & Unwin, 1988); Jeffery T. Richelson, *America's Space Sentinels: DSP Satellites and National Security* (Lawrence, KS: University Press of Kansas, 1999); Curtis Peebles, *Guardians: Strategic Reconnaissance Satellites* (Novato, CA: Presidio Press, 1987); and Burrows, *Deep Black.*

war.[13] Arnold was right; the next war was technological and it came to be known as the Cold War. Later, on 1 July 1958, the Air Force Ballistic Missile Division published a new development plan for WS-117L with the title "New Horizons." In 1998, Air Force Space Command published its official history of the air force in space, *Beyond Horizons: A Half Century of Air Force Space Leadership*.[14] In addition, since 1959, satellite controllers have used the word "support" to describe any contact with a satellite, indicating their significant role in its existence. "Supporting New Horizons," the title of my dissertation, therefore, plays on words, because although they do not fly and fight, military satellite command and control operators make essential contributions to the air force mission of defending the United States and protecting its interests through air and space power.[15]

In the post-1945 period, the evolution of satellite command and control began with the Douglas Aircraft Corporation's Research and Development division (later the RAND Corporation) report on the possibility of a "World-Circling Spaceship."[16] RAND scientists and engineers produced the report in a rush after World War II because the airmen did not want to be left out when they found out the navy was looking into the

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[13] Theodore Von Kármán with Lee Edson, *The Wind and Beyond: Theodore von Kármán, Pioneer in Aviation and Pathfinder in Space* (Boston: Little, Brown and Company, 1967).

[14] David N. Spires, *Beyond Horizons: A Half Century of Air Force Space Leadership* (Washington: Government Printing Office, 1998).

[15] "USAF Fact Sheet," http://www.af.mil/news/factsheets/usaf.html, accessed 17 Jan. 2002.

[16] Project RAND, "Preliminary Design of an Experimental World-Circling Spaceship," Report No. SM-11827 (Santa Monica, CA: Douglas Aircraft Company, Inc., 2 May 1946; reprint, Santa Monica, CA: RAND, 1996).

usefulness of satellites. When the navy turned its attention to other things, air force leaders filed the RAND report away for a decade. With the launch of Sputnik in October 1957 and with the space race and the Cold War in high gear, the United States covertly accelerated its plans to develop a reconnaissance satellite.

Discussions about satellite command and control also went on outside the air force. Independent of the military, NASA developed an extensive satellite tracking network for Vanguard, the first American scientific satellite program. The United States in fact developed two separate but equal satellite command and control networks, NASA's public one, and the military's private one, designed specifically to support the top secret National Reconnaissance Program. During the 1960s, the air force system of satellite command and control supported the new horizons of Arnold and von Kármán but did not achieve any important new capabilities for the air service. This dissertation will show that the military satellite command and control system evolved in the 1960s solely to support the National Reconnaissance Program.

When considering the evolution of the military satellite command and control system, a model of the social construction of technology articulated by historian Thomas Parke Hughes helps explain the system's development.[17] Models are generally associated

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[17] From his lifetime of work, see especially Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983); "Emerging Themes in the History of Technology," *Technology and Culture* 20 (Oct. 1979): 697-711; "Technological Momentum in History: Hydrogenation in Germany, 1898-1933," *Past and Present* 44 (Aug. 1969): 106-132; "The Development Phase of Technological Change: Introduction," *Technology and Culture* 17 (July 1976): 423-430; "The Evolution of Large Technological Systems," in Wiebe Bijker, Thomas Parke Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*

with social scientists, not scholars in the humanities, but it is nevertheless appropriate to study the evolution of this large technological system, given what others have written about similar technological systems. That is not to say that models are the only method for studying the history of technology. Nor is it to suggest that historians can only study the Air Force Satellite Control Facility using this particular model. In addition, part of the problem with using a model is that it is often a more thematic than a straight chronological approach. This particular model, though, does keep the story on a generally chronological path. Nevertheless, this model of the social construction of technology provides meaningful insights into the way human beings created this large technological system for satellite command and control.

The first phase in the model is the invention phase, when the system's inventors solved critical problems. These teams of inventors who insisted on independence from larger research and development organizations produced a new type of system with unique capabilities. During development, the second phase, the social construction of technology becomes clear, as engineers transformed the invention of satellite command and control into an innovation, embodying in the system the economic, political, and social characteristics it needed to turn their ideas about satellite command and control into an operational satellite command and control system. During the innovation phase, the third phase of the model, the product came into use for the National Reconnaissance Office. As the satellite command and control system expanded in the fourth phase, the growth phase, problems developed as components in the system fell behind or out of

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(Cambridge: MIT Press, 1989), 51-76; "The Electrification of America: The System Builders," *Technology and Culture* 20 (Oct. 1979): 124-161.

phase with the others, sometimes without warning. Engineers overcame these "reverse salients" by designing new components that could handle increased requirements, turning the system into a real network instead of a group of command and control stations bound together in a military organization. The independent command and control network built for the weather satellite program reveals in its differences, however, that the system did not have to evolve the way it did, and in fact shows that other systems could be developed to challenge the AFSCF's place as the premier provider of satellite command and control services.

Finally, technological systems do not become autonomous; they acquire momentum, an organizational and technological mass that pushes them along. As engineers overcame each reverse salient, they built momentum into the satellite command and control system that kept potential customers away, an unusual choice for a large system. A new technology, the Space-Ground Link Subsystem (SGLS), helped overcome technological momentum by making the AFSCF useful for every satellite program in the Department of Defense (DoD) and valuable for some NASA programs as well. At the same time, SGLS helped the AFSCF overcome momentum building in the large numbers of personnel still required to operate the system by replacing them with technology. By the end of the 1960s, the United States Air Force gave up on the idea military performing operations and maintenance in the Air Force Satellite Control Facility, falling back on having contractors perform the vital national service of satellite command and control. The momentum of the AFSCF also arose from the organizations committed to the system. Engineers, managers, owners, investors, civil servants, and

politicians all had vested interests in the growth and existence of the military's system of satellite command and control. The momentum in the special relationship between the NRO and the air force continued as the AFSCF supported its patron, often at the cost of providing support for other national space priorities, with important implications for the future.

Like every large technological system, military or civilian, the AFSCF evolved because of the interaction of human beings with technology, not because the technology evolved autonomously. The development of the air force system of satellite command and control provides an example of how a large technological system evolved as a socially constructed technology. For example, ideas about satellite command and control developed similarly inside and outside the air force, but scientists and engineers built their networks differently because their satellite programs had the very different mission goals of science and reconnaissance. In addition, the AFSCF illustrates a pattern of technological systems development that applies whether the system is a large private venture like an electrical power system or a major government project like a satellite command and control system. Using the Hughes model shows that large governmental systems evolve according to the social construction of technology, but reveals that managers, more than inventors or engineers, influenced this technological system's development.

Developed solely to support the National Reconnaissance Program, the AFSCF had a unique relationship with the National Reconnaissance Office, a secret organization created in 1960 that the American government officially concealed until the 1990s. For

the success of the National Reconnaissance Program, the United States needed ground tracking stations and an integrated command and control system. The special relationship between the NRO and the AFSCF amounts to an example of the social construction of technology at the behest of a particular interest group.

This study, ostensibly a history of the Air Force Satellite Control Facility, may not satisfy many former "Range Rats," as AFSCF veterans like to call themselves. What this dissertation is not, in fact, is a history of the AFSCF, a particular tracking station, or even the entire history of air force satellite command and control. The "old heads" tell those stories themselves in their quarterly newsletter *Downlink.* This work also does not include satellite recovery, an important aspect of the early reconnaissance satellite program, because the recovery pilots did not contribute to the evolution of satellite command and control. Although administratively part of the AFSCF, aerial recovery is not truly part of the story of the development of satellite command and control.

In 1967, well after the first successes of the reconnaissance satellite program, President Lyndon Johnson declared that "if nothing else had come out of [the space program] except the knowledge we've gained from space photography, it would be worth 10 times what the whole program" had cost. "Because of satellites," Johnson said, "I know how many missiles the enemy has."[18] Gen. Bernard A. Schriever, leader of the air force's space and missile efforts during the 1950s and 1960s, tried to develop deterrence

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[18] Day, et al., *Eye in the Sky*, 1.

through strength and capability, not the threat of mutually assured destruction.[19] As he put it later, "I am looking for ways to avoid killing people. . . . We need to do something other than find ways to kill people better."[20] The United States Air Force's ground-based satellite command and control system, built as part of an integrated reconnaissance satellite program, helped take away the veil of secrecy from the face of the Soviet Union, thus reducing the threat of nuclear war between the superpowers.

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[19] Major General B. A. Schriever, "ICBM--A Step Toward Space Conquest" (address presented to the Space Flight Symposium, San Diego, CA, 19 Feb. 1957), provided by General Schriever to the author.

[20] B. A. Schriever, interview by author, Washington, DC, tape recording, 27 June 2001.

CHAPTER 1

"THE INESCAPABLE PREMISE":

INVENTING SATELLITE COMMAND AND CONTROL

. . . no space program is feasible without an adequate ground environment.[1]
-- National Security Council Memorandum 1859, Jan 1959

I remember the direction [sic] came down. "The word 'space' is forbidden to be used. You will not even talk about it. Nobody is interested in space. It's a nonuseful type of endeavor for the military to get into. It's a waste of money, just don't talk about it." We didn't quit thinking about it, but we quit talking about it.[2]
-- Lt. Gen. Thomas W. Morgan, USAF, Retired

Today the air force uses fiber-optics and wideband data streams to distribute data from satellites, but in the early days of space operations, sending telemetry over telephone lines, the most common means of transmitting data in those days from the Alaska tracking station to engineers in California, was more challenging.[3] Telemetry in

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[1] Neil H. McElroy, Secretary of Defense, and T. Keith Glennan, NASA Administrator, "Agreement Between NASA and DoD on Global Tracking, Data Acquisition, Communications, and Data Centers for Space Flight," 10 January 1959, in Paul Kesaris, ed., *Minutes of Meetings of the National Security Council*, Second Supplement [microform] (Frederick, MD: University Publications of America, 1989), 13, A:III:0403.

[2] Lt. Gen. Thomas W. Morgan, USAF, Retired, interview by Dr. James C. Hasdorff, 20-21 March 1984, Jemez Springs, NM, transcript, 32, Air Force Historical Research Agency, Maxwell AFB, AL (hereafter AFHRA), K239.0512-1576. Morgan was the recently retired commander of the air force's Space and Missile Systems Organization in Los Angeles.

[3] For more on the development of the first modulators and demodulators used on telephone lines and the computers built to serve the military's needs, see Kent C.

the 1950s and the 1960s, as it does now, contained important facts about systems status or for calculating a satellite's orbit, not mission data, and was essential for troubleshooting. The data came down from satellites at high speeds, frequency modulated onto sine wave subcarriers, and the tracking station recorded it on magnetic tape. After the satellite passed from view, recorder-operators rewound the tape and brought its speed down until it moved slow enough to transmit on a low data-rate telephone line. They first made a voice phone-call to the data center in Sunnyvale, California, and when the recorder-operator signaled ready to record, the tracking station patched the tape playback in place of the telephone handset, then rolled the tape. Lockheed's satellite engineers often needed a vital piece of data on the tape and transmitting using this method got it to them faster than mailing the tape from Alaska.

Tracking station controllers called the system "Slow-Poke" because the unattended tape usually played back at 1/32nd of the original record speed, requiring thirty-two minutes to deliver one minute's worth of telemetry. Most satellite support operations at the Alaskan tracking stations on Kodiak Island (station call sign KODI) or Annette Island (station call sign ANNE) lasted five minutes or longer, requiring more than two and half hours to retransmit a single satellite support operation's data. Fortunately, the trackers seldom resent a full support of data to avoid tying up the only phone line to this isolated location. Usually they only sent information the command center did not receive during the actual satellite support because of communications outages or that particularly interested satellite engineers. Controllers at the tracking

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Redmond and Thomas M. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge: MIT Press, 2000).

stations had contact with the outside world only through that one phone line and a one hundred word-per-minute teletype machine. If during a transmission, the telephone operator in Sunnyvale needed to connect a northbound call and tapped the KODI or ANNE line to see if someone was using it, she might only have heard funny "beeps" and "boops" on the line. If she thought there was a line failure, she might disconnect the call and log the line out to maintenance. Being in the send-only mode, KODI could not know of the disconnection until the tape ran out hours later, wasting a lot of time. The tracking station controllers eventually let the phone operators know what they were doing wrong, and the phone operators learned about data transmissions. Said one former operator at KODI, "Slow-Poke worked fine, but it sure was slow!"[4]

In those early days of satellites, everyone tried their best to make command and control work, inventing most everything as they went along. As the former Lockheed program manager for the reconnaissance satellite put it: "No one person can claim the responsibility for the design for something as complicated as [a satellite], the Agena [booster], or any large project like that. It's a group effort--there's management, there's specialists."[5] The system did not spring from one person's imagination--no "Eureka!" moment figures in its birth. Engineers borrowed from anywhere and everywhere, using teamwork in the invention process to create the military's satellite command and control system.

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[4] Marv Sumner, electronic mail to author, 11 Jan. 2000.

[5] James W. Plummer, interview with Herbert M. Zolot, 6 and 12 Oct. 1993, tape recording, Colorado Springs, CO., AFSPC/HO.

The larger air force organization had vested itself in existing technology, refusing to nurture an invention--space-based reconnaissance--that by its nature contributed nothing to the organization and even challenged the status quo. The inventors of the military system of satellite command and control, therefore, distanced themselves from the mainstream air force research and development bureaucracy, Air Materiel Command, as well as the normal air force procurement system. The flying air force, uninterested in new technological systems for reconnaissance, did not contribute to the development of this new technology, which threatened obsolescence for airplane-based strategic reconnaissance. In addition, the normal weapons procurement system simply could not bring a radical new weapon system on-line quickly enough for the president, who wanted photoreconnaissance of the USSR in the dark days of the Cold War. The normal air force procurement system took ten years to bring a reconnaissance spacecraft on-line; by contrast, Lockheed and the Central Intelligence Agency took only nine months to get the covert CORONA reconnaissance satellite program launch-ready. Even today, it has taken nearly twenty years to get the air force's next-generation fighter aircraft ready for service,[6] a time span President Dwight D. Eisenhower found impossible to accept in a national intelligence emergency like the ICBM race of the 1950s.

Thus, a unique configuration of free agents contributed to the development of a system of satellite command and control to support reconnaissance satellites. The people who worked at the Western Development Division in the 1950s and 1960s did not invent

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[6] Secretary of the Air Force Daniel Roche, in 2nd Lt André Kok, "SECAF talks command, control during Hanscom visit," http://www.af.mil/news/n20010906_1244.shtml, accessed 7 Sept. 2001.

systems development, but they raised it to a new level. They brought two major missile programs and a satellite reconnaissance program to fruition in just five years, using a developmental program they called "concurrency," spurred on to success by their self-determination.[7] These independent teams of inventors began their work in the 1950s by simply by reading reports others wrote; they finished by creating a satellite command and control system to support the National Reconnaissance Program.

Independent Inventors Roaming Free

New and radical inventions occupied the minds of some airmen at the end of World War II. Chief among the air force visionaries was Gen. Hap Arnold. The Wright brothers taught Arnold to fly and he served a distinguished career, culminating as a member of the Joint Chiefs of Staff during World War II, while Chief of Staff of the Army Air Forces. Although he never served in an independent air force, General Arnold's vision and foresight created the most powerful air and space force the world has ever seen. His creative thinking gave people permission to develop radical ideas for problems.

General Arnold fostered close relationships with various civilian academics, in particular, von Kármán, one of the founders of NASA's Jet Propulsion Laboratory (JPL) at the California Institute of Technology in Pasadena. As the end of World War II approached, Arnold asked von Kármán and the AAF Scientific Advisory Group--a group of leading American scientists who advised Arnold--to develop a long-range vision for

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[7] For more on concurrency, see Hughes, *Rescuing Prometheus*, esp. 69-138; and Lonnquest, "Face of Atlas."

the postwar air force. Arnold speculated about "manless remote-controlled radar or television assisted precision military rockets or multiple purpose seekers."[8] Von Kármán's science and technology forecast, *Toward New Horizons*, laid out his vision for the post-World War II air force. Summarizing his report in a December 1945 letter to Arnold, von Kármán acknowledged that "scientific discoveries in aerodynamics, propulsion, electronics, and nuclear physics, open new horizons for the use of air power. . . . The next ten years should be a period of systematic, vigorous development, devoted to the realization of the potentialities of scientific progress. . . ."[9] Von Kármán proposed a relationship between the air force and science and industry that would provide young officers experience in science and industry and thus improve their capacity to make decisions later on in their careers, much like Arnold's own personal experience. Among the report's numerous recommendations were the permanent establishment of a Scientific Advisory Board and the creation of a major research and development command, both of which became reality in the newly independent service.[10] Once independent, the air force institutionalized the report's suggestions, forging the scientific and technological orientation of today's air force.

The United States Navy also had a small core of people willing to think in bold, new ways. In a simple three-page report--including the cover page--the navy got the

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[8] Arnold to von Kármán, 7 Nov. 1944, in Dik A. Daso, *Architects of American Air Supremacy: Gen. Hap Arnold and Dr. Theodore von Kármán* (Maxwell AFB: Air University Press, 1997), 319.

[9] Von Kármán to Arnold, 15 Dec. 1945, in ibid., 321-322.

[10] Ibid., xix. See also Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944-1986* (Washington, DC: Office of Air Force History, 1988).

jump on the other services in the new medium of space. The navy's Bureau of Aeronautics (BuAer) issued Report R-48 in November 1945, "Investigation on the Possibility of Establishing a Space Ship in an Orbit Above the Surface of the Earth," prepared by Lt. Comdr. Otis E. Lancaster and J. R. Moore. The mission for the ship would determine its orbit, but for reconnaissance of enemy positions, "all the necessary information could be obtained in a few trips over the target." Lancaster and Moore speculated that "television or automatic photography could supply the desired information, without personnel [on board]." They found especially interesting "a circular orbit, 22,300 miles above the surface of the earth, where the [space]ship would make one revolution per day. In this orbit, the ship may be kept over a designated point on the surface of the earth. Naturally, the higher the orbit above the surface of the earth, the more difficult it is to establish the orbit."[11]

Fortunately for the air force, Lancaster and Moore underestimated the technical requirements for their proposal. According to Dr. Robert Salter, a BuAer contractor at the time who reviewed the proposal, the navy wanted a single-stage-to-orbit vehicle, presumably to make worldwide launch from ships possible. To achieve orbit using a single stage, however, required a thrust-to-mass ratio of around 95 percent, "about the

[11] Lt. Comdr. Otis E. Lancaster and J. R. Moore, ADR Report R-48, "Investigation on the Possibility of Establishing a Space Ship in an Orbit Above the Surface of the Earth," November 1945, Jet Propulsion Laboratory Archives, 5-492. Provided to the author by Dr. Rick Sturdevant, AFSPC/HO. Lancaster and Moore may have heard about the 1945 Arthur C. Clarke article suggesting a geostationary orbit for communications satellites and then expanded on it.

same mass ratio as an egg."[12] Even at the start of the twenty-first century, scientists and engineers have not been able to achieve such a lofty goal.

Although brief, the Lancaster and Moore report did not ignore the need for satellite command and control, making it a significant first step. The Space-Missile Committee working under Lancaster and Moore assumed that an "experimental space missile" could be orbited at an altitude of about one thousand miles, suggesting that "one objective of constructing and launching such a missile" would be "determination of the feasibility of radio tracking and control."[13] The Space-Missile Committee considered the program only an introduction to the more general problem of satellites, and needed a further elaboration of the bureau's organization and objectives for definitive progress.

Some in the air force quickly saw an obvious threat: if the navy developed a successful reconnaissance satellite, it would threaten the air force monopoly on strategic reconnaissance.[14] The simple BuAer report only directed an examination into the possibility of a satellite, but Maj. Gen. Curtis E. LeMay, Deputy Chief of Staff for

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[12] Robert Salter, interview by Martin Collins and Joseph Tatarewicz, 29 July 1986 and 7 July 1987, transcript, 14, RAND Oral History Collection, National Air and Space Museum Archives, Suitland, MD (hereafter RAND/NASM). Thrust-to-weight ratio is an efficiency factor for total propulsion. A rocket with a high thrust-to-weight ratio will experience high acceleration. To achieve orbit using a single-stage vehicle requires a high thrust-to-weight ratio, currently only achievable with small objects, not large useful satellites.

[13] "Proposal Submitted for Consideration by the Space-Missile Committee," 22 Oct. 1945, 1, JPL Archives, 5-372b. Provided to the author by Dr. Rick Sturdevant, AFSPC/HO.

[14] Robert Frank Futrell, *Basic Thinking in the United States Air Force, 1907-1960*, vol. 1 of *Ideas, Concepts and Doctrine* (Maxwell AFB: Air University Press, 1989), 196-200. Strategic aerial reconnaissance became an officially exclusive air force mission in the 1948 Key West interservice agreement, though the air force acted both during and after World War II like strategic aerial reconnaissance was their private sphere.

Research and Development for the air force, found out about the research and responded on a far-reaching scale. LeMay directed Douglas Aircraft's RAND Group to investigate the possible uses of satellites. Released in May 1946, RAND's response, "Preliminary Design of an Experimental World-Circling Spaceship," offered a comprehensive look at what satellites could do for the military and suggested three missions: meteorology, communications, and reconnaissance. The report outlined four significant technologies for research and development: long-life electronics, video recording, attitude stabilization, and spacecraft design.[15] The flying air force, enamored with aircraft, largely ignored RAND's report.

Even at this very early stage, the 1946 RAND report addressed the importance of tracking a satellite and calculating its orbital parameters, calling for a "series of telemetering stations [to] be established around the equator to obtain the data from the scientific apparatus contained in the vehicle."[16] The report recommended that the first satellites should be placed in orbit around the equator where they could be repeatedly observed from dedicated ground stations. A radar-equipped ground station could measure both range and angle, compute rate of change of altitude, and send a corresponding pulse to the vehicle. A beacon in the vehicle, which acted as a transponder, could also convey information from the vehicle to the ground. Nevertheless, RAND acknowledged, current radar techniques involving radar ranging or Doppler shift

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[15] Salter interview, 45-47.

[16] "Preliminary Design of a World-Circling Spaceship," viii.

did not offer adequate accuracy.[17] Engineers and scientists did understand the radar technology used in World War II, although they had yet to prove its utility for space vehicles.

The RAND scientists and engineers included in the report plans for a global network of tracking stations. For "orbital observation and telemetering," a satellite required some twenty to fifty stations installed or positioned in a belt around the equator, across the Pacific, Ecuador, Brazil, the Atlantic, French Congo, Kenya, the Indian Ocean, and Malaya. The tracking system had to link all these stations with each other or a central director station by rapid communications if engineers were to maintain continuous tracking and telemetering of the "satellite missile," and particularly if they were to guide its return to earth, important if it had a pilot.[18] RAND's estimate of the required number of ground stations proved to be a little high, but their idea of a centralized command and control system proved prescient.

RAND admitted that its scientists and engineers had a lot of research to do. They barely understood the infant technology of transmitting telemetry from guided missiles to ground stations, although American engineers made great strides during the 1940s using captured V-2, Hermes, Bumblebee, and other test missiles. Satellite command and control scientists and engineers could learn from these activities so they launched some

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[17] Ibid., 132.

[18] Ibid., 218.

missiles for their benefit. Eventually, engineers developed, tested, and exercised the entire communication system required in any actual satellite operation.[19]

In the 1940s and 1950s the air force reconnaissance community was wedded to long-range bombers flying reconnaissance missions: "When you wanted to take pictures of something, you just got in your airplane, went out and turned on your cameras and came back and processed the film."[20] Decision-makers rightly sensed that the air force was so committed to an existing technology--aerial reconnaissance--that it would not nurture a new space-based reconnaissance technology.[21] Reconnaissance aircraft like the RB-29, PB4Y-2, and later even the U-2 could not reach every place in the USSR to search for missiles and bombers. President Eisenhower needed an alternative to provide evidence that the Soviets were far behind in missile development.[22] The mainstream air force rejected space-based reconnaissance as technically crude and economically risky and continued to champion piloted reconnaissance aircraft.

Inside the air force, a small but vocal minority of space enthusiasts argued that the notion of spacecraft and satellites had technical practicality. Espousing the cause of

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[19] Ibid., 233; Clayton R. Koppes, *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), 63.

[20] Merton Davies, interview by Joseph Tatarewicz, 12 Dec. 1985, transcript, 35, RAND/NASM. For a frank discussion of "occupationalism" in the United States Air Force, see Carl H. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force* (New Brunswick, NJ: Transaction Publishers, 1996).

[21] Frederic C. E. Oder, telephone interview by author, tape recording, 10 Oct. 2001.

[22] For more on aerial reconnaissance, see William E. Burrows, *By Any Means Necessary: America's Secret Air War in the Cold War* (New York: Farrar, Straus and Giroux, 2001) and John T. Farquhar, "A Need to Know: The Role of Air Force Reconnaissance in War Planning, 1945-1953" (Ph.D. diss., Ohio State University, 1991).

continuing satellite studies at considerable risk to their careers, leaders such as Maj. Gen. Donald L. Putt, Air Force Deputy Chief of Staff for Research and Development, Gen. Hoyt S. Vandenberg, later Air Force Chief of Staff, and General Schriever, kept official interest in satellites and space programs alive. As Gen. Thomas Morgan recalled later, word came down that officers should not talk about such missions because space was a "nonuseful type of endeavor for the military to get into."[23] Yet, in forbidding officials even to speak the word "space," the air force merely acknowledged the character of the new and radical invention.[24]

In the late 1940s, RAND scientists and engineers continued to develop the basis for making satellite control systems a reality. Building on the 1946 report, RAND submitted twelve detailed supplemental studies, aimed at convincing the air force of the usefulness of the orbiting spacecraft. Finally, in January 1948, the Vice Chief of Staff of the Air Force, Gen. Hoyt S. Vandenberg, authorized the air force's Engineering Division to fund further RAND studies of satellite operations. Vandenberg also issued a policy statement that staked the air force's claim for space operations: "The USAF, as the Service dealing primarily with air weapons--especially strategic--has logical responsibility for the satellite."[25] Although the air force did not have a formally approved

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[23] Morgan interview, 32.

[24] Hughes, "Evolution of Large Systems," 58-59; Morgan interview; Bruno Augenstein, interview by Martin Collins and Joseph Tatarewicz, 28 July 1986, transcript, 28, RAND/NASM.

[25] Maj. Gen. L. C. Craigie, Air Force Director of Research and Development, SUBJ: Satellite Vehicles, 16 Jan. 48, with incl. by Gen. H. S. Vandenberg, Vice Chief of Staff of the Air Force, SUBJ: Statement of Policy for a Satellite Vehicle, 15 Jan. 48, to Brig. Gen. A. R. Crawford, Chief, Engineering Division, Air Materiel Command, in

space program at the time, some service leaders had an interest in the possibilities of space and never retracted General Vandenberg's statement. Saying a thing is not as important as doing a thing. The air force had not yet started building a satellite command and control system even though RAND had been talking about telemetry since 1946. Building a satellite for any reason, let alone strategic reconnaissance, endured an extended infancy in the postwar years.

RAND was not the only organization investigating the usefulness of satellites in the early 1950s. The first unclassified publication on satellites came from the British Interplanetary Society in 1951. Little more than a pamphlet, *The Artificial Satellite* speculated on the possibilities for an unmanned satellite and even offered plans for an earth-orbiting space station. Whereas RAND envisioned military applications for satellites, the British Interplanetary Society's ideas of satellite applications emphasized scientific research: "The extension of radio-telemetering into free space will permit studies of radiations, corpuscular and electromagnetic, emanating from outer space."[26] The society recognized the need for telemetry, tracking, and control of space vehicles and commented favorably on "the multiple-channel telemetering systems used in the American high-altitude rocket programme."[27] It was not nearly as remarkable as what RAND produced in 1951.

Joseph W. Angell, Jr., *USAF Space Programs, 1945-1962* (Washington, DC: USAF Historical Liaison Office), Tab A.

[26] L. J. Carter, ed., *The Artificial Satellite: Proceedings of the Second International Congress on Astronautics* (London: British Interplanetary Society, 1951), 52-55.

[27] Ibid.

The first detailed technical report in the evolution of satellite command and control was RAND's 1951 report, "The Utility of a Satellite Vehicle for Reconnaissance." RAND took a major step by stating the technical and engineering possibilities for a reconnaissance satellite employing television techniques for data readout to ground stations. RAND found its earlier satellite advice largely ignored, but its scientists and engineers did not give up, preparing another report for the air force on "The Utility of a Satellite Vehicle for Reconnaissance." RAND people advocated television because they recognized that the satellite must transmit large amounts of data and television seemed the easiest way to do it. In addition, in the early 1950s the reentry and recovery capabilities needed to return an object from outer space through atmospheric heating did not exist. Very heavy copper heat sinks were the only heat-reducing system available. Weight put a tremendous strain on the launch and recovery capabilities at the time, so engineers tried to keep the satellite as small as possible.[28]

Understandably, RAND devoted most of the April 1951 report to the type of orbit needed for a reconnaissance satellite--for example, speed, altitude, shape, and so forth.[29] RAND suggested that the best orbit for reconnaissance of the USSR would be an eighty-three-degree retrograde orbit at an altitude of three hundred miles. At that altitude, the orbit precesses one degree a day, giving the satellite complete coverage of the USSR in

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[28] Davies interview, 36. This problem disappeared in the late 1950s with the introduction of ablative re-entry vehicles, not only quite feasible but also very lightweight.

[29] Salter interview, 47. The report included an artist's conception of a space vehicle that was, according to Salter, "almost a dead ringer for [Lockheed's] Agena" booster.

bright sunlight. It could also give the vehicle longer line-of-sight communication time with ground stations.[30]

RAND also keenly pointed out the need to convey the data recorded by the satellite back to the ground. Assuming they could use television signals to broadcast the data to stations "sited either in friendly territories or on ships," transmission still had to be line-of-sight because of the required radio frequencies, remaining in the AM/FM range (530 KHz to 108 MHz). The maximum slant range from a satellite in a 350-mile orbit would be about fourteen hundred miles, too far for effective data transmission using either AM or FM unless multiple channels could be modulated onto a single carrier wave. Further, this slant range required five stations off the Eurasian landmass, but such an orbit would still miss about 15 percent of the USSR. The possibility of eliminating unobserved areas increased when employing the technique RAND called "delayed broadcasting." RAND nevertheless underestimated transmitting device technology as so bulky and complex that delayed broadcasting did not "appear to warrant any further investigation."[31] Significantly, RAND's report illuminated most of the problems of using a satellite for reconnaissance and raised some important issues in the area of command and control.

RAND's Robert Salter used personal connections at RCA to conduct some research at NBC studios in Hollywood, and figuring out some early parameters of

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[30] James S. Coolbaugh, "Genesis of the USAF's First Satellite Programme," *Journal of the British Interplanetary Society* 51 (Aug.1998): 285.

[31] J. E. Lipp, et al., "The Utility of a Satellite Vehicle for Reconnaissance," The RAND Corporation, R-217, April 1951, in John M. Logsdon, ed., *Organizing for Exploration*, vol. 1 of *Exploring the Unknown: Selected Documents in the History U.S. Civil Space Program* (Washington: NASA, SP-4407, 1995), 249.

satellite command and control. On "the basis of a couple of martinis," Salter did some simulated satellite photography. A year later, when Salter moved over to Lockheed, he took a few highly accurate pictures of the earth and put them on easels. Salter built degradations into the photos that he assumed matched the degradations from space. Using image orthicons, vacuum tubes used in some television cameras, he scanned the pictures in a simulated satellite path, and then transmitted them up to Mount Wilson, near Los Angeles. Rebroadcasting the pictures back through the atmosphere, Salter recorded them using a kinescope because magnetic tape recording had not reached the television studio, a technology that did exist. A group of photointerpreters looked at the pictures to see what they could see.[32] Salter thus proved the viability of space-based reconnaissance of the earth.

RAND devoted considerable attention to the ground tracking stations. A station with an appropriately sized receiving antenna can theoretically track a satellite in a 350-mile orbit for about three thousand miles, horizon to horizon. A satellite would traverse that distance in approximately eleven minutes at an average angular tracking rate of fifteen degrees per minute, requiring the antenna tracking system to be carefully tied in with the satellite's system. RAND assumed the diameters of the satellite's antenna and of the ground station's to be one foot and sixteen feet, respectively, and that the ground station's antenna would be small enough for reasonable engineering in mounting.

RAND engineers preferred using a receiver in the satellite responding to a continuous-wave signal of a ground beacon to direct the satellite antenna toward the

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[32] Salter interview, 48.

ground station. Before the satellite appeared over the horizon, the ground station began transmitting its electronic "greeting." This electronic handshake required establishment of an orbit sufficiently precise so that the azimuth angle at which the satellite appeared above the horizon with respect to a given ground station could be predicted to within one or two degrees. Once the two had made their radio connection, the ground station's receiving antenna could follow the satellite by means of a tracking receiver locked on the television signal. RAND speculated that to make it all work, a beacon having a power gain of about one thousand watts would yield a broad enough beam to illuminate the satellite when it rose above the horizon.

Because of a ground station's size and the fact that it did not move much (while satellites moved a lot), considerations of circuit complexity and power consumption did not affect ground station design, which could take any of several forms. The ground station's sixteen-foot receiving antenna could have a single feed connected through a power receiver to two receivers, for system redundancy. The search phase consisted of aiming the axis of the dish in the direction of the satellite's scheduled appearance and then oscillating the dish back and forth through its axis so that the axis of the scan would describe an arc centered on the direction of the satellite. When the satellite appeared, the satellite's tracking antenna first could contact the ground station's beacon, thus aligning the satellite's transmitting antenna with the ground station.[33] RAND believed that a single ground station would be necessary, suggesting its location somewhere in Alaska, perhaps Fairbanks or Point Barrow, believing that weather, communications, and

[33] "Utility of a Satellite Vehicle for Reconnaissance," 250-55.

transportation would all be sufficient, even so far north.[34] RAND's proposals and research in fact came very close to the system fielded in the early 1960s.

With the tracking problem seemingly solved, RAND turned its attention to assimilating the TV pictures after they arrived at ground level. The equipment required at any forward receiving station would not be complex, and in fact, would be similar to television broadcasting gear then in use. Any ordinary television receiver would probably suffice for monitoring purposes to check for satisfactory picture quality. For recording, a station would need a second television receiver. Camera optics would reduce the image to the appropriate film size; RAND thought thirty-five millimeter film might be adequate, but if they lost a significant amount of detail, they could employ 70-millimeter film. Schedulers furnished each ground station with a schedule for operations, calculated based on the satellite's orbit. Some sort of time coding would be included with each frame in order to know not only when the satellite took the picture but also when it arrived at the ground station. The central evaluation station, presumably the air force photograph interpreters at Hanscom AFB, Massachusetts, or later, the National Photographic Interpretation Center (NPIC) in Washington, DC, would receive the composite films from the forward stations and assemble the orbit into an integrated whole. The entire presentation system would be simple, rapid, reliable, state-of-the-art, and practical, using well-known photo evaluation techniques.[35] Anyone in the range of the remote tracking station also could easily intercept signals. The report finished up with a discussion of how the enemy might track the reconnaissance satellite, either

[34] Coolbaugh, "Genesis," 286.

[35] "Utility of a Satellite Vehicle for Reconnaissance," 255-61.

actively with radar or passively with cameras similar to the air force's own Baker-Nunn camera, used for ground-to-space observation, an entirely different type of satellite tracking.

In sum, to find solutions to the problems they encountered, the independent inventors of the Scientific Advisory Group and RAND Corporation roamed widely. Von Kármán's report to Gen. Hap Arnold presented a vision for the air force in space. Arnold's successors, although stymied by a conservative organization, turned the vision into reality by seeking out independent research organizations. RAND's reports on the utility of an artificial satellite became the first detailed technical reports in the evolution of satellite command and control. Unlike aerial reconnaissance, the air force did not have a monopoly on interest in satellite command and control.

Invention of Satellite Command and Control Outside the United States Air Force

During the 1950s, the United States had several organizations besides RAND Corporation researching the usefulness of a satellite and the technology of satellite command and control. These organizations all had to overcome the same problems RAND faced in its research, and among the most important was "What do you do with a satellite once you have got it in space?" Without exception, they all came to the same conclusion: gather data. The Minitrack and Microlock satellite tracking networks, which scientists and engineers developed in the 1950s for the Naval Research Laboratory and the Army Ballistic Missile Agency, both innovative but essentially conservative inventions, nevertheless proved the viability of satellite command and control, improved and expanded existing telemetry systems.

After World War II, Johns Hopkins University's Applied Physics Laboratory (APL) broke new ground in space telemetry. Working for the navy on the Bumblebee series of guided missiles, APL made enormous strides in the late 1940s, establishing many of the standards for radio telemetry and introducing sub-carriers on radio frequencies to enhance data transmission capabilities. By the time telemetry matured, engineers and scientists had continuously enhanced and increased the flexibility of ground station equipment. Recording techniques, especially, progressed from making a phonograph record to recording on magnetic tape.[36] Scientists and engineers outside APL borrowed their methods and used them for their own satellite programs.

S. Fred Singer offered his Minimum Orbital Unmanned Satellite of the Earth (MOUSE) to the American Rocket Society in April 1955. In his discussion of the technical problems associated with launching, control, and instrumentation of MOUSE, he made sure everyone understood the ramifications of telemetering, including for the first time in a satellite proposal, channels and frequency modulation. He suggested a polar orbit for MOUSE as the most economical to store data and release it over the poles, either North or South, because this system demanded a minimum of ground stations. Singer drew the same orbital conclusions RAND had drawn, but an international treaty made Antarctica off-limits for anything but purely scientific research, so the South Pole was not an option for RAND's proposed reconnaissance satellite. Singer understood that his proposed test satellite could not perform the types of missions requiring a high degree of orbital precision, like reconnaissance. He noted that optical visibility and the accuracy

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[36] Mayo-Wells, "Origins of Space Telemetry," 499-509.

of the orbit were not important for a satellite with geophysical or astrophysical research applications. Such a scientific satellite required only extremely simple propulsion, guidance, and control in comparison to satellites meant to fulfill more ambitious functions like space-based strategic reconnaissance.[37] Singer's proposal, the first significant proposal for a scientific satellite discussed in non-governmental circles, caught on with the scientific community, but not in the American government.

Scientists and engineers often discussed publicly how best to build the needed tools for communicating with satellites. At the February 1957 Astronautics Symposium in San Diego, cosponsored by the Air Force Office of Scientific Research and the Convair Division of General Dynamics, prime contractor for the Atlas ICBM, experts from Lockheed, RAND, and the Jet Propulsion Laboratory gave papers on satellite tracking. The conference attendees concluded overall that no additional major breakthroughs would be required before an adequate communications system for space travel could be designed. Using systematic exploitation of the techniques and devices already known, electronics engineers could produce communications system performance able to satisfy space travel requirements for years.[38]

Max Fishman, a researcher at Lockheed, suggested at the conference that the size of transmitters and receivers on the satellites themselves might be the biggest problem in

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[37] S. F. Singer, "Studies of a Minimum Orbital Unmanned Satellite of the Earth (MOUSE)," presented to the American Rocket Society, April 20, 1955, in *Exploring the Unknown*, vol. 1, 323-24.

[38] James A. Marsh, "Survey of Communications Problems Associated with Space Travel," in Morton Alperin, Marvin Stern, and Harold Wooster, eds., *Vistas in Astronautics*, International Series of Monographs on Aeronautical Sciences and Space Flight (New York: Pergamon Press, 1958), 85-87.

satellite command and control because early satellite designs had a premium on "legroom." Increasing the bandwidth of the communication link with a satellite dictated the use of either greater transmitted power, increased receiver sensitivity, or increased antenna size. The simplest solution resulted from using increased antenna size on the ground and decreased operating frequencies, which he achieved with a fixed, steerable antenna system.[39] Fishman's ideas eventually found their way into the air force's tracking stations.

Government indifference to satellites faded under the glare of the International Geophysical Year (IGY), an international project of concentrated, coordinated exploration of the earth's cosmic environment, planned for July 1957 to December 1958, but first discussed by the scientific community as early as 1954. Although publicly denying a race with the Soviet Union to orbit a satellite for the IGY forced a decision to go ahead with a satellite program, the United States staked its technological reputation on a quasi-civilian research and development project called Vanguard, a grapefruit-sized scientific satellite that included a plan for radio tracking, called Minitrack, run by the Naval Research Laboratory.

On 26 March 1955, the National Security Council ruled the American scientific satellite program should not use military rockets; the army proposal depended on the new Jupiter IRBM then under development but Vanguard engineers planned an entirely new rocket for their satellite. Then in August 1955, the Stewart Committee, the scientific review panel ordered to choose the American entry for the IGY, formally selected

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[39] Max Fishman, "Satellite Tracking Techniques," in Alperin, et al., *Vistas in Astronautics*, 67-70.

Vanguard as the scientific satellite program. According to Homer J. Stewart, chairman of the panel, Vanguard's Minitrack network had a direct bearing on the decision to accept Vanguard over the Army's Project Orbiter, which planned a visual instead of an electronic tracking network.[40] Vanguard's brand new missile, perceived to be untainted by either the air force or army long-range missile development programs, also helped sway the Stewart Committee.

Vanguard's electronic tracking system used radio interferometry. Essentially, two ground receiving stations tracked the signal from a satellite broadcast and by comparing the phases of the signals, each of them separately received, scientists could accurately calculate angles to the spacecraft, and therefore calculate its orbit. In a sense, radio antennas work much like our ears, able to locate the source of a sound by virtue of the phase differences in the sound waves, arriving at each ear at slightly different times.[41] Vanguard originally included an optical tracking plan, which, although accurate, had its limitations. Using the best equipment, trackers could only observe an object in orbit with the sun at five degrees below the horizon, that is, just before sunrise or after sunset, and even then, visual tracking required clear and relatively cloudless weather.

Vanguard's tracking system became the nation's first dedicated satellite control system. In the early 1950s, Vanguard scientists under Milt Rosen at White Sands, New Mexico, built and field-tested a tracking system for their Viking missile testing. John T. Mengel and his associates came up with a thirteen-ounce transmitter for the Vanguard

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[40] Green, *Vanguard: A History*, 148.

[41] John T. Mengel and Paul Herget, "Tracking Satellites by Radio," *Scientific American* 198 (Jan. 1958): 23-29.

satellite, far smaller than those carried aboard their Viking rockets, but still employing the same system. Mengel gave the tracking system the name Minitrack. Minitrack consisted of a quartz-crystal controlled and fully transistorized oscillator aboard the spacecraft. Its ten-milliwatt output operated on a fixed frequency and had a predicted lifetime of ten to fourteen days.[42] In addition to the tracking function, Minitrack included antennas and receivers to read out the data transmitted by the scientific satellites--in other words, ground telemetry stations.[43]

Vanguard had political limitations on its tracking network that made it useless for tracking reconnaissance satellites. Because they planned to launch Vanguard from Cape Canaveral, the satellites had to go into an orbit limited to thirty-five degrees above or below the equator. An orbit with such an inclination could prove useful for not only tracking reasons but also political ones. Vanguard would not track so far north that it would invade the "space" above the USSR, but could still help setting the precedent for freedom of navigation in orbit above the earth, a major American concern before the first satellite launch.[44] Therefore, to track the satellite, the Vanguard team planned to establish a "picket line" of Minitrack stations along the roughly equatorial orbital path,

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[42] Green and Lomask, *Vanguard*, 146.

[43] John P. Hagen, "The Viking and the Vanguard," *Technology and Culture* 4 (Fall 1963): 445.

[44] Arthur Radford, Chairman, Joint Chiefs of Staff, Memorandum for the Secretary of Defense, "U.S. Scientific Satellite Program," 24 May 1955, in *National Security Council, Minutes of Meetings*, A:III:0403. "It is important to preserve the 'Freedom of Space' concept in order not to impair our freedom of action to launch. . . . Since the mere solicitation of prior consent from any nation over which the satellite might pass in its orbit might jeopardize the concept of 'Freedom of Space,' the proposed policy would preclude any action which would imply a requirement for such prior consent." See also Walter A. McDougall, *...the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), esp. Chapter 7.

eventually placing stations on the islands of Grand Bahama, Antigua, and Grand Turk, as well as in South Africa, Australia, and South America, leased with the help of the navy and the Department of State, and in the United States. These seven stations formed a picket line that had a 90 percent chance of tracking every pass of the planned three hundred mile orbit.

The system introduced the concept of control from a central location. The Bendix Corporation built the ground station equipment, including the radio-frequency receivers, power supplies and operating consoles, the phase measurement equipment, analog and digital recorders, and quartz-crystal oscillator clocks. Melpar, Inc., built the AN/DPN-48 radar beacons for tracking. Observers at the tracking sites sent information by teletype to the Vanguard Computing Center in downtown Washington, where technicians fed the figures into an IBM-709 "electronic calculator," contracted to the government at $900,000 for six weeks (including a back-up capability at IBM headquarters in upstate New York).[45] As the stations collected observations along various points of the orbit and controllers transmitted them back to Washington by teletype, technicians fed them into the computer that calculated Vanguard's orbit. The program included corrections for atmospheric drag and the wobble of the orbit due to the Earth's bulge, and could give a minute-by-minute position 150 times faster than Vanguard actually flew.[46] Minitrack centered its communications network in Anacostia, Washington, DC, from which teletype connections were established to Cape Canaveral and all the tracking stations, as well as to the Vanguard Computing Center. From one central location, then, scientists

[45] Green and Lomask, *Vanguard*, 158-161.

[46] Mengel and Herget, "Tracking Satellites by Radio," 27.

followed and controlled the whole progress of Vanguard's tracking and data acquisition, the first example of what other satellite systems would achieve.[47] The conservative Vanguard tracking system did not push the state-of-the-art because engineers used existing technology.

Just before going operational in late 1957, the system faced its first test. All the Minitrack equipment operated on the IGY frequency of 108 MHz, later the edge of the civilian FM radio band. In October 1957, the Soviet satellite Sputnik operated at 20 MHz and 40 MHz, the same as American ham radio frequencies. Minitrack engineers quickly tried to get as many stations as possible retuned for this *de facto* operational test, scrambling to get new oscillators and instructions out to all the ground stations. Most of the stations never got accurate data on Sputnik, but the stations at Lima, Peru, and San Diego, California, picked up good tracking data on both Sputnik I and Sputnik II (which launched a month later). The IGY committees had chosen 108 MHz because it would give a more accurate indication of direction for tracking purposes, but the Sputnik frequencies nevertheless yielded information about the ionosphere and its effects on radio frequencies.[48] Sputnik demonstrated that the nascent American tracking system worked, although it did not include any flexibility.

Vanguard's Minitrack became the nation's first ground-based space tracking network, but engineers had designed it for only one satellite program and operated it at only one frequency at a time--both major shortcomings. Minitrack operated full-time as a worldwide satellite network, but it did not provide common-user support. Minitrack had

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[47] Hagen, "The Viking and the Vanguard," 446.

[48] Mengel and Herget, "Tracking Satellites by Radio," 28.

35 full-time tracking and data acquisition facilities in operation, and another 15 shared or part-time facilities, but all supported a single satellite at a single frequency. In addition, virtually no capability existed for polar orbits, and Minitrack could only support about half of orbits with inclinations over 51 degrees, thus making it virtually worthless for a satellite reconnaissance system reconnoitering the USSR. The only programs fully supportable were those at 35 degree inclinations and transmitting at 108 MHz like the Vanguard satellite itself. The meager data acquisition capabilities included only low bandwidth capabilities and only if also using magnetic tape to record data and send it by mail to the central office. Teletype only transmitted the most rudimentary data in real time. Eventually, the Minitrack shortcomings became so pronounced that NASA and DoD proposed the creation of a national tracking program on the "inescapable premise that no space program is feasible without an adequate ground environment" at a total cost of $41 million for FY 1959.[49] When Vanguard finally orbited successfully, Minitrack served it exceptionally well, but its shortcomings limited its usefulness for an American system of satellite command and control supporting a reconnaissance satellite.

Other important developments in satellite command and control occurred on the West Coast. Scientists at JPL generated some technical innovations that proved significant in terms of what they lent to the programs that would follow. The receiver in JPL's Microlock, a phase-locked loop tracking system picking up very small signals at great distances (under ideal conditions a one-milliwatt signal 6,000 miles away), was an

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[49] Neil H. McElroy, Secretary of Defense, and T. Keith Glennan, NASA Administrator, "Agreement Between NASA and DoD on Global Tracking, Data Acquisition, Communications, and Data Centers for Space Flight," 10 January 1959, in *National Security Council, Minutes of Meetings*, 13, A:III:0403.

impressive innovation. As adapted in 1955 for the army's Project Orbiter studies, which eventually became Explorer, the first American satellite to achieve orbit, Microlock separated out five telemetry channels. Explorer also included a tape-playback system that made possible storing data and transmitting it when in view of a ground station, which Explorer would not be for most of its orbit. In 1958 Explorer III even contained a miniature tape recorder that moved at the slow rate of 0.005 inches per second, using less than three feet of tape per orbit, a prototype of satellite-based recording systems in use today. When the satellite neared a tracking station, a ground signal turned on the playback head and the high-powered transmitter. In less than five seconds, the satellite sent all the data on those three inches of tape, erased it, and reset.[50] Many of Jet Propulsion Laboratory's innovations found their way into satellite programs for years.

For the scientists and engineers at the Jet Propulsion Laboratory, the problems of tracking Explorer called attention to the need for a worldwide tracking system. On a dry lake one hundred miles from Pasadena, a huge revolving dish eighty-five feet in diameter rose out of the Mojave Desert. Because in those days only minimal ambient radio "noise" reached out that far from Los Angeles, and because of the dry desert weather, Goldstone proved ideally suited to set up the Deep Space Network, soon to provide support for all aspects of American civilian spaceflight, and a vital part of JPL's activities. The Jet Propulsion Laboratory engineers received approval for foreign stations in Australia, Spain, and South Africa.[51]

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[50] Koppes, *JPL and the American Space Program*, 80-91.

[51] Ibid., 95.

The American Mercury space program also required a worldwide tracking network to support the astronauts. Of all the efforts in support of these pilots, NASA had the most difficulty establishing a new tracking network from scratch. When flight surgeons decided they needed to have constant contact with the astronauts, Mercury program engineers realized they had to create a worldwide tracking and communications network, with gaps of no more than ten minutes. They knew the technically immature Minitrack network already in place had too many gaps in its coverage to meet the flight surgeons' ten-minute criterion and so did not suit their needs. In February 1959, the Space Task Group at NASA Langley put together an *ad hoc* team that built a telemetry, tracking, and control network in two years.[52] NASA, therefore, built its second worldwide tracking network to serve the needs of its piloted, low-declination space program. The Mercury network stretched from the Mission Control Center at Cape Canaveral to eighteen communications relay stations on three continents, seven islands, seven foreign countries, and two ships. It used 177,000 miles of hard-wired communications lines, most of which would be leased; 102,000 miles of teletype; sixty thousand miles of telephone lines; and over fifteen thousand miles of high-speed data circuits, all cross-linked and connected to NASA's Goddard Center in Maryland where

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[52] Swenson, et al., *This New Ocean*, 214-216; see also James R. Hansen, *Spaceflight Revolution: NASA Langley Research Center from Sputnik to Apollo* (Washington: NASA, SP-4308, 1995), 67. Hansen nicely fits the development of the tracking station networks into Langley's (and NASA's) overall story. This work includes anecdotes about survey trips for the tracking stations, including a story about a team that set down in the Congo in 1966 to do a survey for a Mercury tracking station, and found themselves in the middle of the first Congolese Revolution.

two IBM 7090 computers calculated orbits in "real-time."[53] NASA estimated the total cost for the system in 1959 at $41 million.

For the fifth launch of a Mercury spacecraft on board an Atlas booster (MA-5), the tracking network performed flawlessly. Unfortunately for Enos, the chimpanzee sitting inside, the same could not be said for the incorrectly wired systems inside the spacecraft, which shocked him repeatedly even though he did his tasks correctly. The tracking network's first challenge in real-time came near the end of his first orbit when the trackers noticed the spacecraft clock was eighteen seconds fast and they sent a command to reset it. The Canary Island and Western Australia stations detected other problems but Woomera could not confirm them. By late 1961, NASA had rated the tracking network for human flight and prepared MA-6, John Glenn's *Friendship 7*.[54] This tracking network formed the nucleus of NASA's tracking network for piloted spaceflight all the way to the moon.

The Minitrack and Microlock tracking networks, and their offspring used in Mercury, both innovative but essentially conservative inventions, improved and expanded existing systems; engineers did not invent radically new systems. The later Air Force Satellite Control Facility began its evolution as part of a radical new system of satellite reconnaissance, but became essentially a conservative system as well. Ideas about satellite command and control developed similarly inside and outside the air force, but engineers built the networks differently because the space programs had different

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[53] Swenson, et al., *This New Ocean*, 217-220. The $41 million dollar figure for the cost of the Mercury tracking network is about $251.5 million in 2001 dollars.

[54] Ibid., 405-409.

missions. In effect, therefore, the United States had two tracking networks, one civilian and in the open, one military and in the background.

Summary

Although separate from the mainstream, the air force did not invent satellite command and control on its own; a variety of independent inventors, free from the constraints of large industrial or governmental organizations, developed solutions to the problems engineers and scientists encountered. The air force, for example, received assistance from a group of scientific advisors who represented the best minds in the nation and from the RAND Corporation to find answers to questions the air force could not answer alone. General Hap Arnold gave Dr. von Kármán wide latitude for his report *Toward New Horizons*. Later, Douglas Aircraft's RAND Group produced a series of reports on the utility of a "World-Circling Spaceship," which eventually became the first technical reports in the history of satellite command and control. In addition, General Schriever had unprecedented autonomy in developing the ICBM and the reconnaissance satellite. He did not give details about his programs through normal air force channels, but instead reported with the highest national priority directly to the Secretary of the Air Force and the President of the United States.

The independent inventors of satellite command and control--RAND Corporation, the Naval Research Laboratory (Vanguard's Minitrack), and the Jet Propulsion Laboratory (Explorer's Microlock)--distanced themselves from their larger organizations. Large organizations vested in existing technology rarely nurture inventions that by their nature contribute nothing to the organization and even challenge the status quo, so the air

force went outside, to the Scientific Advisory Group and the RAND Corporation, and found answers to questions it alone could not answer. These independent inventors roamed widely, choosing solutions to the problems they encountered, each according to their own unique situations. RAND's series of reports on the uses for satellites became the first technical reports in the history of satellite command and control, specifically endorsing the idea of a satellite for strategic reconnaissance, which fell under air force purview.

The invention of satellite command and control came in two forms, conservative and radical. The Minitrack and Microlock tracking networks and their offspring used in Mercury, while innovative, were essentially conservative inventions, improving and expanding existing systems, not radical inventions launching entirely new systems. The air force system of satellite command and control developed out of radical ideas about satellite-based reconnaissance. We can consider, therefore, both satellite reconnaissance, and the air force satellite command and control network it spawned, radical ideas.

Ideas about satellite command and control developed similarly inside and outside the air force, but scientists and engineers built their networks differently because their satellite programs had the very different mission goals of science and reconnaissance. During the next developmental phase in the evolution of satellite command and control, the social construction of the military's technological system becomes even more clear, as engineers transformed the invention by using the radical ideas expressed in the RAND reports to build a system of satellite command and control to support a space-based satellite reconnaissance system. Along the way, they endowed the new system with the economic, political, and social characteristics it needed to survive.

CHAPTER 2

"OF VITAL STRATEGIC IMPORTANCE":

DEVELOPING A SATELLITE COMMAND AND CONTROL SYSTEM

> I think the smartest, most aggressive, best motivated people are blue suiters. I believed it when I was in the Air Force and believe it now, and wish I [were] still in the Air Force. So, it's not a question of are they capable of doing the job. The question is whether that is the best use of the resource.[1]
>
> -- Lt. Gen. Forrest McCartney, USAF, Retired
> Former Commander of the Space Systems Division

> We cannot be fearful of failures, and thus attempt only the sure things, which result only in a short-term gain.[2]
>
> -- Brig. Gen. Homer A. Boushey, 23 April 1958
> Deputy Director of Research and Development

In the early 1950s, nobody knew how to build antennas capable of tracking a low-earth orbiting satellite, so the air force and its contractors learned as they went along. During construction of the earliest ground stations to support the National Reconnaissance Program, mechanical problems plagued the command and control antennas. Because the analog transmitters on board the satellites sent only weak signals, the tracking stations needed big reflectors to acquire the transmissions. Enormous

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[1] Forrest S. McCartney, telephone interview by author, tape recording, 9 Nov. 2000.

[2] Homer A. Boushey, U.S. Air Force Deputy Director of Research and Development, 23 April 1958, in *Astronautics and Space Exploration*, Hearings before the Select Committee on Astronautics and Space Exploration, 85 Cong., 2d Sess. (Washington: Government Printing Office, 1958), 525.

antennas on the ground also compensated for the limited power available on the satellite. Lockheed and Philco, the Philadelphia-based radio company that served as Lockheed's subcontractor on the tracking stations, mounted the big parabolic dishes--some seventy feet in diameter--to ensure movement in all three axes. Technicians had difficulty pointing an antenna with accuracy and stability in high winds because the dishes vibrated and oscillated, especially the antennas that Lockheed furnished. Philco furnished antennas that one former program officer recalled were "built like battleships." Making the pedestal for the modified World War II-era SCR-584 radar antennas out of inch-and-a-quarter-thick boilerplate, Philco undertook a major challenge installing and outfitting them. In fact, Philco only built two or three of these expensive and heavy antennas. A screeching of motors and grinding of gears because of an antenna's great mass often accompanied stopping its motion. The drive motors could just barely move the antenna at a rate that could let it track a low-orbiting satellite like the reconnaissance satellite, which moved from horizon to horizon in roughly five minutes. They did a lot of rework and argued many times about the antennas and their construction.

As the technology improved, it became evident that the spacecraft could transmit a stronger signal, meaning the dishes could be lighter. The air force and Lockheed went to a smaller antenna, the AN/TLM-18, just eighteen feet in diameter. Lockheed supplied and reworked some of the base structures for the TLM-18s several times in order to make

them three-axis tracking antennas. After some delay, Lockheed finally completed an expert technical installation of the expensive antennas.[3]

Space operations clearly had a steep learning curve, but in fact, the development of the Air Force Satellite Control Facility typifies large technological systems in the twentieth century. For example, Admiral Hyman Rickover presided over the development of the nuclear navy as an engineer-entrepreneur.[4] He involved himself in the areas of funding, research and development, manufacturing, organization, management, and politics. Thomas Edison, an inventor-entrepreneur, had competence as an inventor but not as an engineer, whereas Admiral Rickover had competence as an engineer, not as an inventor. In the evolution of the air force system of satellite command and control, one cannot point to a person who stewarded the AFSCF as Rickover did the nuclear navy or Edison did electrical power networks.[5] We can consider the Air Force Ballistic Missile Division, Lockheed and Philco, as the inventor-entrepreneurs because they combined the "invented" and "developed" physical components into a complex

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[3] Thomas O. Haig, telephone interview by author, tape recording, 16 Oct. 2000. Later, the Air Force Satellite Control Facility mounted sixty-foot antennas on surplus navy five-inch twin gun mounts, based on modification instructions that the Massachusetts Institute of Technology provided under a DoD contract (*History of the Air Force Satellite Control Facility*, 1 July 1966-31 Dec. 1966, Atch 7, 3, AFSPC/HO, Box 3-3-2, Folder JD-66). The Soviets did something similar at Yevtaporia, Crimea, the main control center for piloted space missions, where they had an array of eight sixteen-meter antennas. Sergei Korolev, Soviet Chief Designer, took advantage of the revolving gun turret of a former battleship destined for the scrap heap by placing it on a foundation. The open framework of a railroad bridge was placed over the turret. The solid hull of a scrapped submarine covered the bridge and workers affixed the antennas to this hull (Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945-1974* (Washington: NASA, SP-2000-4408, 2000), 536.

[4] See Richard G. Hewlett and Francis Duncan, *Nuclear Navy, 1946-1962* (Chicago: University of Chicago Press, 1974).

[5] Hughes, "Emerging Themes in the History of Technology," 703-4.

system of manufacturing and service facilities. In fact, the development of the Advanced Reconnaissance Satellite system helped bring into being several major organizations, including aerospace giant Thompson-Ramo-Wooldridge, federally-funded research and development corporations such as RAND and the Aerospace Corporation, and a military satellite command and control system.

To develop the technology, engineers constructed test environments that became successively more complex and more like the world that system would encounter in operation. To accomplish the important task of development, the large organization inventing and developing the satellite command and control system assigned subprojects and problems to different types of professionals. This chapter will show how, as engineers strove to develop satellite command and control into a system to support the reconnaissance satellite program, they continued to give the military's system of satellite command and control everything it needed to function in the new physical environment not only of space, but also the social environment of politics and high technology.

Embodying Economic, Political, and Social Characteristics into the System

While developing the technical components of the military's system of satellite command and control, the inventor-entrepreneurs of the air force system of satellite command and control--the air force's Western Development Division, aerospace corporation Lockheed, and radio corporation Philco--also embodied in their invention the political characteristics it needed to survive in the maze of government agencies. This unexpected intersection of society, politics, economics, and technology, resulting in a

transformation of one technology's function, exemplifies what historians have come to understand as the social construction of technology. The inventor-entrepreneurs of the military system of satellite command and control and their associates embodied in their invention economic, political, and social characteristics. Satellite command and control, therefore, changed from a relatively simple idea into a complex technological system infused with various factors. The Air Force Satellite Control Facility's inventor-entrepreneurs introduced economic, political, and social changes during its development as it grew and became indispensable to American military satellite command and control.[6]

In 1951, Air Research and Development Command (ARDC) authorized the RAND Corporation to make specific recommendations for the start of developmental work on a reconnaissance satellite system. RAND recommended in Project Feed Back that as a matter of "vital strategic importance" the air force should begin studying the "use of an efficient satellite reconnaissance vehicle."[7] Then a major, William G. King, Jr., read the Project Feed Back reports that addressed such matters as orbital mechanics and satellite photography of the earth, believing in the plausibility of such space capabilities in the near future. The RAND studies, and King's own earlier observation of ballistic missile launches at both White Sands Army Proving Ground in New Mexico and

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[6] Hughes, "Evolution of Large Systems," 59-64. Historian David Noble presented another opinion of the social construction of technology by arguing that engineers built the interests of management into digital machine-tool systems for the purposes of controlling the working class. See David F. Noble, *Forces of Production: A Social History of Industrial Automation* (Oxford: Oxford University Press, 1984).

[7] J. E. Lipp and Robert M Salter, "Project Feed Back Summary Report," RAND Corporation, Report R-262, 1 March 1954, Defense Technical Information Center, Ft Belvoir, VA (hereafter DTIC), AD354297.

the Joint Proving Grounds in Florida, convinced him that the United States could perform some military missions in space. King subsequently helped establish a system program office, known as the Advanced Reconnaissance System Program Office. After briefing the secretary of the air force, King had $2 million for systems concept studies of military satellites.[8]

RAND sold ARDC on the idea of satellites by proposing them as a system designed to test the feasibility of building a satellite, complete with estimates of costs, development time, and critical design criteria. In early 1953, ARDC's program office for the Advanced Reconnaissance System recommended acceptance of the RAND proposal for letting a system design contract within one year. Unfortunately, from December 1953 to January 1954, ARDC did little beyond documenting the reconnaissance satellite proposal as Project Number 409-40, "Satellite Component Study," engineering project MX-2226, ARDC M-80-4, Project 1115; tentatively assigning it the designation Weapon System 117L; and giving it the unclassified name "Advanced Reconnaissance System."

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[8] Air Force Space Command History Office, "Brigadier General William G. King, Jr.," *Air Force Space and Missile Pioneers* (Colorado Springs: Air Force Space Command, 2000), 11. Topeka, Kansas, native William G. King, Jr., received an ROTC commission at Kansas State University, entering active duty during World War II and serving as an antiaircraft artillery officer in the Pacific Theater. After the war, this early architect of the Air Force's Advanced Reconnaissance System--if such a term should even apply to individuals--returned to Kansas State, completing his B.S. in 1946. He later received a master's degree from the University of Chicago in business administration, with an emphasis on the management of research and development. General King retired from the air force in April 1971, beginning an eighteen-year career with Aerojet General Corporation, where he served as both vice president and general manger of the Space Surveillance Division of the Electronics Systems Division, and as Director of the Defense Support Program, the nation's ballistic missile early warning satellites.

Although convinced of the utility of a satellite for reconnaissance, King still had to sell it to the air force as an operational system, not just a fancy research project. Strategic Air Command (SAC), the air force's nuclear command responsible for President Eisenhower's doctrine of massive retaliation, expressed interest in the uses of the Advanced Reconnaissance System. In mid-1955, King traveled from ARDC headquarters in Dayton to SAC headquarters in Omaha, Nebraska, to speak about the Advanced Reconnaissance System. At the start of the meeting, someone yelled "Attention," and everybody stood up. In walked SAC Commander-in-Chief General LeMay with "half-a-dozen of his horse holders." King often introduced his presentation by saying, "I'm here to tell you about the Advanced Reconnaissance System, the ARS. The arse. Now, some of you people don't know your 'ARS' from a hole in the ground, and I'm going to straighten you out." He often got a laugh, but this time, with the hard-nosed, cigar-chewing General LeMay sitting right in front of him, King decided he had better not use his "arse" joke. King started his presentation a little awkwardly, a young major in front of an air force legend, but he thought LeMay paid attention to the talk. When the general got up after the presentation, King knew for sure LeMay had been paying attention. LeMay walked by King and said, "How did you fellows justify your TDY [travel money] to come in and tell me such crap?"[9] LeMay, a career pilot and responsible for strategic aerial reconnaissance as commander-in-chief of Strategic Air Command, soundly rejected the idea of satellite-based reconnaissance, which he actually

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[9] Brig. Gen. William G. King, Jr., USAF, Retired, telephone interview by author, tape recording, 25 Oct. 2000. When King returned to Ohio, his boss, Lt. Gen. Howell M. Estes, Jr., a LeMay protégé, gave King a stern talking to. King's "sales trips," however, continued.

had initiated in the air force when he served as chief of R&D for the air service. Later, LeMay did become a supporter of satellite-based reconnaissance, but at the outset, satellite systems were a tough sell to the legendary air force leader.

Unfortunately for the space enthusiasts, the air force did not commit itself to fight for the embryonic satellite program. No operational air force command bought into the idea of a reconnaissance satellite, so it remained up to ARDC to define and develop the entire Advanced Reconnaissance System. Even though the air force came to a decision on 27 November 1954 to support a reconnaissance satellite program, and even though ARDC published System Requirement No. 5, covering satellite reconnaissance, the air force still allocated no funds to cover development. So the Advanced Reconnaissance System remained a research project until 16 March 1955, when Air Force Headquarters published General Operations Requirement No. 80, which called for the development of a satellite reconnaissance vehicle for use by a combat command.

In the 1950s, politics and space were nearly inseparable. The first American policy statement on space came from the National Security Council on 20 May 1955 in the classified document NSC 5520, "Draft Statement of Policy on U.S. Scientific Satellite Program." President Eisenhower took a keen interest in the discussions in the National Security Council, often attending meetings and taking an active role in the discussions, which considered three satellite programs in early 1955, including WS-117L.[10] The policy statement stressed the political benefits of having the first satellite launched under international auspices as part of the International Geophysical Year. According to the

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[10] See Fred I. Greenstein, *The Hidden Hand Presidency: Eisenhower as Leader* (New York: Basic Books, 1982), especially 129-31.

National Security Council's report, DoD studies indicated that the United States could launch a small scientific satellite weighing five to ten pounds into orbit using adaptations of existing rockets.[11] This small project fit well within President Eisenhower's vision for space. The United States had an official American IGY entry, Vanguard, but the country still had no national policy on satellite reconnaissance.

The National Security Council also recognized the need for "tracking facilities" as part of the overall cost of the program despite the small American IGY effort. Unfortunately, it is not entirely clear from the statement just what "tracking" meant. "Tracking" might have meant just watching satellites through passive, visual means, or it may actually have meant command and control of space vehicles. The National Security Council concluded that if they made a decision to embark on a space program promptly, the country would probably be able to establish and track such a satellite within the period 1957-58. The National Security Council estimated $20 million would guarantee a small scientific satellite for the IGY, allowing for "adequate . . . observation costs," implying visual observation. The $20 million estimate included $2.5 million for "instrumentation for tracking," and another $2.5 million for "logistics for launching and tracking."[12] Looking carefully at Annex A, the technical appendix to NSC 5520, the details become clear about tracking the scientific satellite; the National Security Council, still largely concerned with passive, optical tracking of the IGY satellite, understood the advantages of "electronic techniques" for tracking satellites.

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[11] National Security Council, NSC 5520, "Draft Statement of Policy on U.S. Scientific Satellite Program," 20 May 1955, in *Exploring the Unknown*, vol. 1, 308-9.

[12] Ibid., 310.

The National Security Council insightfully recognized the need for satellite command and control and the political consequences it had for the entire American satellite program. Any satellite fixed in a highly elliptical orbit, for example, two hundred miles by one thousand miles, passes completely around the earth in about ninety minutes. If controllers selected an orbit over the earth's poles or an orbit inclined to the equator, a satellite passed successively farther west of the launching point on each revolution because the earth rotates under the satellite's orbit. Significant for command and control, an individual tracking station set up for inclined orbits cannot be in an observing position for every revolution. Therefore, the optimum location for tracking polar orbits is at or near the poles because the earth does not rotate as far away from a satellite's orbit.

There were political problems with polar tracking stations. In 1955, the United States had a base near the North Pole, Thule Air Base in far northern Greenland, a Danish possession. Thule at the time was home to thousands of American airmen and B-52 bombers flying on hair-trigger nuclear alert. The United States also had a presence on Antarctica, at the South Pole, which was protected from any military activity first by American policy and later by the 1959 Antarctica Treaty. Neither polar basing option seemed useful for scientific purposes because of their distance from the continental United States and the difficulty in reaching them. A more inclined orbit, especially one inclined at 90-degrees and nearly polar, substantially reduced the usable data per station for scientific experiments based on passive, optical observations.

A better political solution in the mid-1950s was to choose an equatorial orbit. An equatorial orbit placed a tracking station in a position to observe every orbit of a satellite. The usefulness of the IGY scientific satellite and the selection of a desirable orbit both depended on the degree to which the satellite could be acquired and tracked by electronic or optical techniques. NSC 5520 suggested, therefore, that the United States set up tracking stations to gather data on the new satellite at the Navy Air Missile Test Center, Point Mugu, California; the Naval Ordnance Test Station, Inyokern, California, White Sands Proving Ground, New Mexico, the British-Australian Guided Missile Range, Woomera, Australia, as well as at a number of astronomical observatories, presumably for passive, optical observations as the earth rotated under the satellite.[13] While the National Security Council debated the political issues related to a scientific satellite, the air force continued to plan for a tracking system for a reconnaissance satellite, which needed polar orbits.

Based on the RAND studies, in early 1955 the Advanced Reconnaissance System program office in Ohio put out a Request for Proposal targeted at specific companies from which the air force would issue development contracts. When the Request for Proposal for WS-117L went out, the air force gave the Advanced Reconnaissance System a new program name, PIED PIPER. Lockheed, Glenn L. Martin Co., and RCA all decided to submit proposals. The air force offered Bell Labs and IBM, two other electronics firms, money to study the idea, although both declined.[14] The air force

[13] Ibid., 311.

[14] Salter interview, 48-49.

provided $1 million to Lockheed, Martin, and RCA for research, giving the corporations plenty of research latitude.

Observers outside the air force assumed that RCA, a big electronics firm heavy in data processing, had the upper hand over the two old-school airplane companies, Martin and Lockheed. These people did not take into consideration that the airplane companies had an advantage that RCA did not: they had been involved in selling systems to the air force for years, so the airplane companies understood the air force procurement system much better than RCA did. Martin and RCA recommended an electronic video system, not too far removed from the original RAND proposal for a readout satellite, and the narrowness of their proposal hurt them both.[15] The air force accepted neither bid from RCA or Martin.

Lockheed's President, L. Eugene Root, on the other hand, enlisted some of the best minds in the burgeoning space industry to help his company's proposal. A former RAND employee, Root recruited Robert Salter, Bruno Augenstein, William Fry, and Sidney Brown from the original team of RAND "World-Circling Spaceship" engineers and scientists. Augenstein eventually became chief scientist of Lockheed's satellite program, and then moved on to the defense department, working under Harold Brown, Defense Director of Research and Engineering during the Kennedy and Johnson administrations. James W. Plummer, a Salter protégé, later served as Under Secretary of the Air Force and Director of the National Reconnaissance Office in the Nixon and Ford administrations. Other engineers and scientists joined Lockheed and together they made

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[15] Salter interview, 49; Davies interview, 31.

a difference for the airplane manufacturer trying to make its way into the realm of space contractors.[16]

Lockheed took a broader approach to the problem of satellite reconnaissance because of its unique combination of experienced scientists and engineers, including in its proposal to ARDC for both video and film reconnaissance systems. Louis Ridenour, formerly of MIT's Radiation Laboratory and the first chief scientist of the air force, gave Lockheed's presentation to ARDC, very much impressing the review board. Lockheed included in its proposal a host of other functions for the satellite system besides visual (photo) reconnaissance, including infrared surveillance, communications surveillance, and others. Lockheed also wrote the proposal in the ARDC format for development plans, spelling out the system requirements, how they planned to develop the system, how they planned to train personnel, maintain and operate the system, and even where the tracking stations ought to be.[17] According to Robert Salter, Lockheed's proposal originated the requirement for launch facilities at Camp Cooke, "which Schriever liked because he wanted something up there. He received that with open arms."[18] Unlike the competition, Lockheed proposed a complete satellite system to the air force. General Schriever recalled later "it turned out that the companies which had been engaged in aircraft weapon development were among the most competent companies in the country

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[16] Augenstein interview, 33; Air Force Space Command History Office, "James W. Plummer," *Space and Missile Pioneers*, 16.

[17] Salter interview, 49.

[18] Ibid.; Coolbaugh, "Genesis of the USAF's First Satellite Programme," 293; Oder, electronic mail to author, SUBJ: Early 117L, 28 Jan. 2000.

reconnaissance satellite (identified then as a "data readout system," what the air force would later call the SENTRY program). Ritland and his team left the meeting with the impression that he had convinced the government to accelerate the reconnaissance satellite program. Still, nothing happened because Air Force Secretary James H. Douglas, Jr., felt that the engineers still "overestimated" the roles there might be for satellites in orbit.[21]

In June 1956, General Schriever officially announced that the review board had selected Lockheed over RCA and Martin as the prime contractor for the WS-117L program, still known as PIED PIPER, but again the reconnaissance satellite system suffered a setback. On April 2, the Western Development Division had published a development plan for WS-117L, calling for full initial operational capability by 1963 and research and development costs of $153 million.[22] The air force approved the development plan for PIED PIPER on 24 July 1956, but allocated a mere $4.7 million, 3 percent of Lockheed's estimate. In November, new Air Force Secretary Donald A. Quarles told the Western Development Division to cease development on the scientific satellite. "Don't bend any metal," Quarles told them, knowing that the United States

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[21] James H. Douglas, Jr., interview by Hugh H. Ahmann, 13-14 June 1979, Chicago, Ill., transcript, 126, AFHRA, K239.0512-1126; Osmond J. Ritland, interview by Lyn R. Officer, 19-21 March 1974, Solano Beach, Calif., transcript, 231-235, AFHRA, K239.0512-722.

[22] Western Development Division, *WS-117L Advanced Reconnaissance System Development Plan*, 2 Apr 1956, AFHRA, K243.8636-39. $153 million 1956 dollars is just over $1 billion 2001 dollars.

already had a very public scientific satellite program with its own tracking network, Vanguard.[23]

Domestic politics over space prevented major funding for the program. The United States had yet to decide which organization should have responsibility for space. Senior air force leaders wanted to make sure that the government and the public thought of the air force as the nation's space service. In a November 1957 speech to the National Press Club, Air Force Chief of Staff Gen. Thomas D. White, echoing the theme Gen. Hoyt S. Vandenberg first articulated in 1948, once again asserted the air force claim to space.

> In speaking of the control of air and the control of space, I want to stress that there is no division, per se, between air and space. Air and space are an indivisible field of operations. . . . Ninety-nine percent of the earth's atmosphere lies within 20 miles of the surface of the earth. It is quite obvious that we cannot control the air up to 20 miles and relinquish control of space above that altitude . . . and still survive.[24]

Thereafter, White frequently used the term "aerospace" to make his point that the air force should be the service for all military missions above the surface of the earth.

White's efforts to claim space for the air force did not stop with speeches. The air force released the 1959 edition of Air Force Manual 1-1 (AFM 1-1), *United States Air Force Basic Doctrine*, with references to "space" as an operational air force mission. Issued under General White's signature, the manual used "aerospace power" in place of the old term "air power." AFM 1-1 also abandoned the idea of gaining a "dominant

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[23] Oder interview by author.

[24] General Thomas D. White, "At the Dawn of the Space Age," *Air Power Historian* 5 (Jan 1958), 17. This article is a reprint of a speech he gave to the National Press Club on 29 Nov. 1957.

position in the air" in favor of an objective of obtaining "general supremacy in the aerospace."

> The aerospace is an operationally indivisible medium consisting of the total expanse beyond the earth's surface. The forces of the Air Force comprise a family of operating systems--air systems, ballistic missiles, and space vehicle systems. These are the fundamental aerospace forces of the nation. . . . That nation, or group of nations, which maintains predominance in the aerospace--not only its military forces but also in its sciences and technologies--will have the means to prevail in conflict.[25]

Because air power and space power both operated above the surface of the earth, the air force took the position that the United States should vest control of air and space in a single military service which, whatever its official name, would be *the* aerospace force. Thus by 1959, the air force had convinced itself that it should take the lead in space operations, but it had not convinced anyone else, especially not the supreme political and military authority in the United States, President Eisenhower.

On 4 October 1957, everything changed. RAND, who had defined the feasibility of using a satellite for reconnaissance within the current state-of-the-art in its April 1951 secret report, stepped back to the forefront. The report languished in the "back of the files" until Sputnik's dramatic launch, when, said RAND space pioneer Scott J. King, "You never saw a file opened so dammed fast in your life!" King remembered people saying, "'What the hell did RAND say back there? Let's get cracking on this thing.'"[26] Recalled General Schriever, "When Sputnik went up . . . everybody was saying, 'Why

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[25] United States Air Force, *AFM* [Air Force Manual] *1-2, Air Doctrine, United States Air Force Basic Doctrine*, 1 Dec. 1959, quoted in Robert Frank Futrell, *Basic Thinking in the United States Air Force, 1961-1984*, vol.2 of *Ideas, Concepts, Doctrine:* (Maxwell AFB: Air University Press, 1989), 714-5.

[26] Scott J. King, interview by Martin Collins and Joseph Tatarewicz, 22 July 1987, transcript, 14, RAND/NASM.

the god dammed hell can't you go faster? Who's in charge here?'"[27] The air force did accelerate the reconnaissance satellite program, but did not move it into the fast lane. Instead, the service spent funds on its major strategic nuclear buildup and pushed the development of ICBMs, leaving satellites a lower priority.

The air force's Scientific Advisory Board, which had first suggested the study of pilotless aircraft in *Toward New Horizons*, urged acceleration of the reconnaissance satellite program. In a May 1956 report, the Scientific Advisory Board recommended "VIGOROUS SUPPORT AND EXPANSION" of the reconnaissance satellite program because

> To launch a group of satellite vehicles and maintain them in orbits several hundred miles above the earth seems to all of us a great enterprise linked to the traditions of . . . the Wright Brothers' airplane. . . . The instrumented earth satellite is one of the most exciting adventures in the Air Force research and development program.[28]

In a December 1957 memo to Air Force Chief of Staff General Hoyt S. Vandenberg, Scientific Advisory Board Chairman (and National Advisory Committee on Aeronautics Chairman) Jimmy Doolittle urged acceleration of the reconnaissance satellite development program.[29] In a planned speech before the Air War College in 1957, Air

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[27] Schriever interview by author.

[28] "Report of the Scientific Advisory Board Reconnaissance Panel on Reconnaissance from Satellite Vehicles," 28 May 1956, Dr. Carl F. J. Overhage, Chairman, AFHRA, K243.012-34.

[29] MEMO, J. H. Doolittle to USAF Chief of Staff, 9 Dec. 1957, 3, AFHRA, K168.8636-10.

Force Undersecretary for Research and Development Trevor Gardner also urged more rapid development of "the so-called space satellites."[30]

When the CIA got involved, the entire nature of the reconnaissance satellite program changed, but not the Air Force Satellite Control Facility. The CIA had had the U-2 for overhead reconnaissance for some time, but the aircraft had limited capability and President Eisenhower only reluctantly employed it. Eisenhower also did not want to admit publicly that the United States had an active reconnaissance satellite research and development program, particularly after Soviet Premier Nikita Khrushchev rejected the "Open Skies" proposal. So Col. Ritland sat down with Richard Bissell at the CIA and created the DISCOVERER cover story about an environmental satellite test program. The two had successfully created the U-2 reconnaissance aircraft and teamed up again on the reconnaissance satellite. The new reconnaissance system received a quick go-ahead for development. The air force now had public authorization to develop a prototype demonstration satellite capability using a Thor IRBM with an upper stage, eventually aimed at providing a demonstration of launch, orbit, and recovery. Privately, the CIA acted as the overall program manager, using air force resources and air force contractors to do the job, a return to the arrangements of the U-2 development program. So, although the air force started it, the CIA predominantly funded the reconnaissance satellite program.[31]

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[30] Trevor Gardner, "Foreseeable Scientific and Technological Trends as they Apply to Military Technology and Strategy," 28 May 1957, 10, AFHRA, 168.7171-232.

[31] Ritland interview, 238a.

Government leaders already understood the significance of satellite command and control and its importance for national defense. Nevertheless, the social construction of the Advanced Reconnaissance System should be clear at this early stage. As the invention developed, the inventor-entrepreneurs and their associates embodied in their invention the political characteristics it needed to survive in the maze of government agencies. In addition, it had the sponsorship of a major American defense contractor, Lockheed, and a major government development agency, the Air Force Ballistic Missile Division. As the invention changed from a relatively simple idea into a complex system, the military system of satellite command and control continued to experience economic, political, and social changes in its development, as it grew and became indispensable to American satellite command and control.

Systems Engineering in the Air Force Satellite Control Facility

Another important aspect of this stage in the evolution of a large technological system is that large organizations developing a system often assign subprojects and problems to different types of professionals.[32] In 1954, General Schriever's Western Development Division began using a particular management scheme for developing the Atlas ICBM, which they called "concurrency." The new management system stemmed from the realization that neither industry nor the air force then had sufficient in-house competence to undertake the broad technical management of ballistic missile weapon systems and the urgency of the international military situation called for strong measures

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[32] Hughes, "Evolution of Large Systems," 64.

to expedite the program. Schriever, therefore, surrounded himself with an unusually competent group of scientists and engineers, capable of making systems analyses, supervising the research phases and controlling the experimental and hardware phases of the ICBM program. As the aerospace industry's competence increased, a number of companies appeared, fully capable of managing the development of weapon systems of similar complexity.[33]

On the other hand, the air force's "in-house" capabilities to plan, analyze, and procure complex systems did not reach the point where the service could direct the development of such systems without contracted assistance from companies with high scientific and technical competence. The capability problem also extended to air force space programs, which Schriever handled in Los Angeles. Technical assistance, therefore, had to come from a civilian contractor with a privileged position. The problem became balancing the urgent need for rapid development with the lack of technical competence in the air force while giving no appearance of favoritism to one contractor over another. The air force itself recognized that any appearance of impropriety

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[33] *Report of the Secretary of the Air Force Management Study Committee*, Clark B. Millikan, Director, 29 Jan. 1960, 1-3, AFHRA, K168.8636-26. For a more detailed look at how General Schriever and his team arrived at the decision to use systems engineering and technical direction contractors, see Hughes, *Rescuing Prometheus*, and Lonnquest, "The Face of Atlas." For a highly critical view, see Edward N. Hall, *The Art of Destructive Management: What Hath Man Wrought?* (New York: Vantage Press, 1984); Colonel Edward N. Hall, "Epitaph," 29 August 1958, Ballistic Missiles Division, ARDC, AFHRA, K243.0122-7; Colonel Edward N. Hall, interview by Jack Neufeld, Washington, DC, 11 July 1989, transcript, AFHRA, K239.0512-1820; Thomas O. Haig, "Systems Engineering and Technical Direction as a Management Concept," Student Research Report No. 67, (Washington, DC: Industrial College of the Armed Forces, 1966), provided by Colonel Haig to author; and Haig interview by author.

endangered its relationship with the contractors it needed to have to build a successful space and missile program.[34]

The air force did not use system engineering in the WS-117L program, although one former program manager wishes they had.[35] Because of this important context, it is worth investigating the character of systems engineering and technical direction as well as the way the concept affected the technological style of the Air Force Satellite Control Facility. The concept is still important today in the Air Force Satellite Control Network; in fact, the network could not operate without the individual network integrators at each station who are expert in station technical configuration.[36]

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[34] *Report of the Secretary of the Air Force Management Study Committee*, p. 3; "Brief History of Aerospace Corporation," in U.S. Congress, House, Committee on Government Operations, Military Operations Subcommittee, *Systems Development and Management*, 86th Cong., 1st sess., 1958, 1129-1134; Ritland interview, 253-54.

[35] Oder interview by author.

[36] The author's experience with systems engineering and technical direction has shown him that the concept works. While stationed at the Diego Garcia Tracking Station between April 1996 and April 1997, in his role as the Quality Assurance specialist, the author spent a lot of time with the site's systems engineering and technical direction contractor, Lenny Carter. Carter's many years of experience on Diego and in the satellite control network was absolutely invaluable for the smooth operation of the station, especially when it came to integrating new equipment into the station. With the 1996 closure of the Indian Ocean Station in the Seychelles, Diego Garcia became the only station in the unclassified American system of satellite control between the United Kingdom and Guam. Therefore, when NASA wanted to transfer its quad-helix UHF antenna from the Seychelles to Diego, the contractor team had a major challenge on their hands--how to integrate the 1960s-vintage NASA equipment with the 1990s-era air force system. NASA used the quad-helix antenna to relay data from the ARIA flying tracking stations to the ground. NASA engineers and Lockheed contractors on Diego Garcia, with Carter's help, merged the ARIA data stream with the regular Diego Garcia data stream and shipped the data back to the NASA controllers at NASA Goddard in Maryland. The first success in 1996 was the Mars Global Surveyor satellite, NASA's orbiting mapping satellite of Mars. The transient lifestyle of the air force officers who rotated through Diego Garcia every twelve months could not match the experience of someone who had lived on Diego Garcia for years.

General Schriever and the leadership in charge of ICBM development understood that the air force did not have the expertise to build a major space system. No one in the air force had a strong background in ballistic missiles in the 1950s. They also knew that no single company in the country had the overall capability to develop and manage the ICBM program on its own. To solve the dilemma, they found companies throughout the United States with the greatest expertise for the various subsystems like guidance, propulsion, and so on. The ICBM leadership also felt that no company had the management skills to develop the ICBM. Even these missile zealots knew the air force would not transition solely from airplanes to missiles; they simply had another weapon system for strategic warfare.[37] The missile development leadership made the decision to recruit some of the best brains in the United States into a new type of management organization, a specifically technical management organization. The Ramo-Wooldridge Corporation, which had split off from Hughes Corporation, had a nucleus of about fifty highly technical people who had been involved in the initial study of the ICBM. Schriever decided that they could provide the needed management skills for the ICBM program as an associate contractor.

Dr. Simon Ramo served as executive vice president of Ramo-Wooldridge, later Thompson-Ramo-Wooldridge (TRW). He knew that the ICBM and the reconnaissance satellite had complex technical problems, which covered a large number of disciplines that the technical direction contractor had to pull together. To meet this need, he recruited people from various fields--aerodynamics and control and heat generation and

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[37] Bernard A. Schriever, interview by Major Lyn R. Officer and Dr. James C. Hasdorff, 20 June 1973, transcript, 40-41, AFHRA, K239.0512-676.

so on. Ramo also recruited a peculiar form of generalist that he thought of as a "systems engineer," someone who had the faculty to understand enough of each of the pieces and could communicate his ideas well. In other words, these systems engineers became the integrating contractor by understanding the trade-offs and seeing what to give or add so engineers could make the weapon system compatible and harmonious.[38]

To reduce the possibility of a conflict of interest, TRW separated the part of the company engaged in manufacturing and created a wholly owned subsidiary called Space Technology Laboratories (STL), with retired air force General Jimmy Doolittle as the chairman. Schriever and Ramo wanted STL to be a transitional activity, which could do the systems engineering and technical direction for the space and missile programs.[39] STL recruited people from all over the country and at one time had over twenty-five people on two- or three-year leaves of absence from top American universities working in California on the ICBM problem.[40] In theory, Space Technology Laboratories got the best talent, used their expertise, and then returned them to their universities.

While the air force built the space and missile program, Space Technology Laboratories played the prime role in describing the various tasks, without building anything. For instance, what did the reentry contractor do? STL's contract included defining those tasks. The air force, that is, General Schriever, always had the final decision, and he had some good colonels helping. Then, a separate group, consisting

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[38] Dr. Simon Ramo, interview by Martin Collins, 27 June 1988, Los Angeles, California, http://www.nasm.edu/nasm/dsh/transcpt/ramo1.htm, accessed 4 Sept. 2001.

[39] Ibid.

[40] Schriever interview by Officer and Hasdorff, 41.

only of military people, made up a list of contractors eligible for competition and invited them to come in and bid for a particular project. STL made the detailed presentation about the task and answered any questions the visiting contractors had. Ramo personally involved himself heavily in the presentations. The invited contractors then made their proposals, while STL listened to their presentations and carefully read their proposals. STL offered their comments on the substance of the proposals, analyzing and rating them. After the presentations, the STL experts stepped back and the military made the decision because the military had other considerations that they included in the decision-making process that STL did not. For example, the air force considered the record of a company in previous, particularly recent, procurements. How did they adhere to the niceties of contract control? How did the air force auditors view them? Then, presumably everything else being equal, the air force gave the work to the contractor that needed it most and had people to assign to the contract.[41]

Colonel Osmond Ritland joined the missile development team in Los Angeles in 1956 as General Schriever's deputy. Ritland felt that the decision for Space Technology Laboratories to do systems engineering and technical direction made sense until they decided they wanted to get into the hardware business as well. STL proposed the first Delta stage, built from the Thor vehicle, but Schriever's system forced STL to turn the drawings over to another contractor, in this case Douglas Aircraft, which built the launch vehicle. When Schriever got permission to proceed with WS-117L production, STL wanted part of the production business. They found the answer in creating Aerospace

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[41] Ramo interview.

Corporation, a new, noncompetitive organization, because STL, the technical direction contractor, a for-profit company, had insight into profit-making opportunities. Aerospace Corporation became responsible for the ballistic missile and space oriented engineering, research, and planning projects that STL had previously performed. By January 1961, seven months after incorporation, the Aerospace Corporation's staff totaled about seventeen hundred employees, adding nine hundred more over the next five months, including six hundred technical people.[42] The new, nonprofit Aerospace Corporation, a captive, government-controlled organization, had sole responsibility for systems engineering and technical direction, with no authority but to make recommendations.[43]

The systems engineering and technical direction contractor provided valuable continuity in this major weapon system development program. Air force officers moved every three years, sometimes faster. Now a retired Philco employee, Howie Althouse, moved from operations and maintenance to system integration in 1966 and spent the next 29 years in integration and engineering, providing continuity and direction for the program. "The last [five] years of my management career [were] spent trying to provide direction and remind the customer what the job was! All the customer seemed to be able to focus on was budget[; they] had no idea what the job was!"[44] According to one former military operator, the air force relied on the contractors because the service did not have the capability: "The guys in the blue suits were way over their heads," in part because of

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[42] House, *Brief History of Aerospace Corporation*, 1132.

[43] Ritland interview, 255-56.

[44] Howard Althouse, electronic mail to author, SUBJ: "NBTS," 12 Dec. 2000.

the military philosophy of giving young officers a lot of responsibility early in their careers. Said retired Col. Mel Lewin, one of the first air force officers to operate a satellite, "We were operating at a level far beyond that which we would be operating if we had been out in industry. Most of us were pretty young. I think we needed industry and I think they did a good job." Developing a space command and control capability at that time with military engineers would have been difficult. The air force simply did not have people with years of background in the nuts and bolts of satellites. The very capable people running the programs had a lot of respect in the technical community.[45] As a former military satellite operator put it, "If you're not violating the laws of physics, you can do anything with enough resources. You can go to the moon in ten years. This country did that. The challenge is trying to get the job done on limited resources. That's the challenge of the Air Force today."[46] Doing the job with limited resources continues to be the challenge inside and outside government today, and the purpose of integrating contractors is to make sure it gets done right.

Not everyone believed in systems engineering and technical direction as the solution to all the air force's technical problems. According to Colonel Haig, contracting out system engineering and technical direction robbed air force personnel of the opportunity to assume true responsibility and authority in engineering situations--situations where an engineer is required--and kept them from doing good, original,

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[45] Col. Melvin Lewin, USAF, Retired, telephone interview by author, tape recording, 21 Dec. 2000.

[46] McCartney interview by author.

responsible work. Instead, systems engineering and technical direction made engineers into managers.

> There is no reason why you can't write a contract with a contractor for the technical direction part of a program, as well as the production part, within his own company and use your own engineers, then, as participants in this program and as people who do their engineering and direct the contractor properly. I'm completely convinced that the "blue suiters" that I have met are at least the equal to anybody I ever met in STL, Aerospace, or Ramo-Wooldridge.[47]

In Haig's mind, the air force could not retain engineers it had paid to put through school in the first place, thus wasting time, money, and effort. The whole Ramo-Wooldridge concept--systems engineering and technical direction assignment outside of the direct line between the producer and the government--has been highly detrimental to the air force in that regard, Haig felt, far more than it has been a benefit. "Aerospace turns right around and . . . talks a guy that's in the air force into resigning or retiring and then hires him, and then the Air Force pays for him at double or triple the salary over there at Aerospace Corporation. It's stupid. It's a dumb system. And, the air force is the only service that really does this."[48] The army departed from their arsenal system at Huntsville and then stopped using systems engineering and technical direction. The navy, also, does not use systems engineering and technical direction. Only the air force uses systems engineering and technical direction contractors and continues to believe in it, which is consistent with the close cooperation between the air force and industry that has existed since the birth of the military airplane.

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[47] Haig interview by author.

[48] Ibid.

Haig also believed that the systems engineering and technical direction concept made satellite systems development larger and more costly than it needed to be. Removing the experts from overseeing the contractor led to vast increases in costs. When he left the weather satellite program four years after starting it, only fifteen people worked in the program office. The office had grown from five to fifteen people, mostly because five officers from Strategic Air Command, the eventual operator of the satellites, constantly rotated through the office to learn the system. The program office also had more secretaries. "God, we'd gotten up to four secretaries," recalled Haig, "so we still had about six productive people, about five SAC people, and four secretaries to handle the increasing amount of paperwork as we moved toward 'normalization.'"[49] Normalization referred to the placing of the weather satellite program under standard government procurement regulations. Haig achieved operational capability for the weather satellite program with one secretary, four air force engineers, and a contractor that built the satellites, but he did not have a systems engineering and technical direction contractor at any time while he ran the program.

After he retired in 1968 as Assistant Director for R&D for the NRO, Haig had occasion to visit his old program office out in California. It had grown to 120 military and civilian people, and an equal number of Aerospace employees. They managed exactly the same program, but did not have any development work because the contractor had already built the ground stations by that point. In addition, the program office had no

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[49] Thomas O. Haig, "Interview with Colonel Thomas O. Haig," interview by Major David Arnold, *Quest, The History of Spaceflight Quarterly* 9 (Jan. 2002): 55 (hereafter *Quest* interview).

more booster development to do. The program office only *monitored* the contract for the satellites. Unfortunately, they managed the program so poorly that the National Reconnaissance Program went without weather satellite support for over two years. The National Reconnaissance Office originally meant the weather satellites to fly ahead of the CORONA vehicles so that the camera operators could set the cameras to take pictures of targets on the ground rather than cloud formations, meaning less wasted film. "What happened was that they 'normalized' everything. They went back under the 375-series [procurement] regulations, and in five years they had had six program directors. The Air Force was assigning non-engineer fighter pilots as program directors to get that on their records so they could be promoted."[50] General Ritland had pointed out--although he could do nothing about it--that a single officer in charge of a satellite program office for a reasonable period of time could do a better job than if the leadership style changed four times with four different officers. Each officer had a tendency to impose different directions on a given program. Even the personality involved in a change slowed a program down as the people got used to the new leadership. Ritland felt such rotation consumed time and led to inefficiency.[51]

When Colonel Haig visited his old program office in 1968, he wanted to learn the details of the latest sensors going on the spacecraft at that time. When he asked a program officer if he knew about the sensors, he pointed to the shelves behind him and said, "It's all there in those books." "Have you read the books?" Haig asked. "Oh, no, I

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[50] Haig interview by author.

[51] Ritland interview.

don't have to read that shit," the officer answered.[52] Haig started the weather satellite program office with a handful of people, and he knew everything about the spacecraft. Lou Ricks, an air force captain in the office, knew everything about ground operations, and in fact simplified the whole tracking procedure by creating a lot of nomograms and tables, entirely getting rid of the necessity for a computer to do the tracking. Ricks got the angles from the tracking stations for the first couple of passes, put them through his nomograms (charts representing numerical relationships between multiple variables used for predictions) and came up with an orbital ephemeris. Then he predicted the next satellite pass over a tracking station, refined his ephemeredes after two or three supports, achieving better accuracy each time.[53] Certainly easier than a massive number of punched computer cards, Ricks's system still relied on the expertise of one person to get the job done.

Similarly, the father of the solid-fueled Minuteman ICBM felt the same way about systems engineering and technical direction, calling it "the biggest mistake ever made."[54] Before leaving the Air Force Ballistic Missile Division in 1958, Colonel Edward N. Hall, who had been in Los Angeles since 1954, wrote a severe, fifteen-page, typed, single-spaced memorandum. In the memo, Hall suggested that Johannes Kepler had reduced the physical laws of ballistic missiles to mathematics long before the Cold War, making ballistic missiles far simpler than bombers or even most jet fighters. Hall felt that the

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[52] Haig interview by author.

[53] Haig, *Quest* interview, 55.

[54] Hall interview, 1.

importance of having a ballistic missile to counter a Soviet ICBM drove air force adoption of the systems engineering and technical direction method. But by continually deferring to "relatively naïve" groups of scientists and encouraging them to believe they possessed a unique competence in the development of complex weapon systems, the air force destroyed its own capability to carry out its assigned task of defending the nation.[55]

Certainly the answer lies somewhere in between the two extremes. Looking at both sides of the issue reveals the technological style driving the creation of the Air Force Satellite Control Facility, which is why it is important to look at the systems engineering and technical direction method in this context, too. The systems engineering and technical direction method contributed an important part of the history of the creation of the air force system of satellite command and control, integrating not just blue-suit operators and contractors, but contractors outside the normal procurement system into the construction of this command and control system. The air force used systems engineering and technical direction in order to achieve a space-based reconnaissance capability faster than doing it without industry's cooperation, relying on others to solve the difficulties of developing the military system of satellite command and control.

Assigning Problems to Others

Before any more expansion of the invention into an operational satellite command and control system, the Air Force Ballistic Missile Division and its partner, Lockheed, had to figure out how to handle an increasingly large number of projects and subprojects.

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[55] Hall, "Epitaph"; Hall interview, 5. When introduced at the Space and Missile Pioneers induction ceremony, TRW founder Simon Ramo held out his hand to Hall. Refusing to shake Ramo's hand, Hall said, "I know who you are, you son-of-a-bitch."

Its origin as Subsystem H of Weapon System 117L meant that the Air Force Satellite Control Facility supported a research and development program to demonstrate air force capabilities for the launch, command, control, and recovery of instrumented space vehicles for reconnaissance. In January 1958, a few months after Sputnik's launch, the reconnaissance satellite system received formal but covert government approval, and in March 1958, the air force issued a contract to Lockheed for five ground stations.

The air force divided its satellite project into three distinct satellite programs but identified the command and control function separately from all three. Satellite command and control consisted of a control center, called the Satellite Test Center, and a number of remote tracking stations and all the equipment and software required to track and control satellites during ascent, on-orbit, and recovery operations. Lockheed planned to put the Satellite Test Center near its facility in Sunnyvale, California. The air force agreed to Sunnyvale because of Lockheed's major presence there and the room available for growth in the area at the time. Close quarters at the Air Force Ballistic Missile Division headquarters prevented location of an operational activity in Los Angeles. The AFBMD called the small group of air force people in Sunnyvale a Field Test Force. Originally located in a Palo Alto Lockheed facility, two people staffed the Field Test Force, one air force lieutenant colonel and one Lockheed engineer. Subsequently, AFBMD designated them as a separate military unit reporting to General Schriever; Lt. Col. Charles A. ("Moose") Mathison served as the first commander.[56]

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[56] Frederic C. E. Oder, electronic mail to author, SUBJ: "Early 117L," 10 Nov. 1999.

In order to handle a satellite's requirements, engineers had to add specific equipment, subsystems, and remote tracking stations to the Satellite Test Center's network. At first, an antenna connected to a specific receiver interfaced with its own program-peculiar control, display, and command equipment. Telephones and a one hundred word-per-minute teletype circuit connected the ground sites to the Satellite Test Center in Sunnyvale. Computers both on the ground and in orbit on spacecraft remained a few years in the future. The equipment at existing remote tracking stations required hours or even days to reconfigure and check out for each of the several programs the air force had in development. The unwillingness of contractors involved in the development of satellite hardware to cooperate with Lockheed, particularly in the sharing of information, also prevented some development because they suspected that Lockheed could gain an advantage in future satellite procurement competitions.[57]

Nevertheless, a cooperative the mood settled over the Air Force Ballistic Missile Division in the late 1950s as the air force tried to get the Atlas ICBM built in record time. In testimony before Congress, General Schriever called the ICBM a "team effort of industry, science and the military." The same mood applied to the air force relationship with its prime satellite contractor, Lockheed. Cooperation did not mean a lack of competition. As General Schriever put it in congressional testimony:

> [Our] philosophy in the program has been competition in two senses: competition among contractors and competitive approaches. We feel that this will get us there sooner, better,

[57] Marv Sumner, electronic mail to author, SUBJ: "AFSCF," 15 Dec. 1999.

> [and] cheaper, and will also provide us a technical backup in case one of these things should fall on its face--which is always a possibility.[58]

Given the limited budget they had to work with, and the national urgency they had added to their goals, cooperation--indeed partnership--between the air force and the prime contractor added to the chances of success.

Not everyone believed that the contractors worked in the best interest of the government. A Lockheed subcontractor, Fenski, Federick, and Miller, installed a projection system meant to allow the satellite operators to gather information in three dimensions. Wearing polarized glasses, not unlike those teenagers wore in movie theaters in the 1950s, satellite operators could see three-dimensional images projected on the screens through two slide projectors. The machine etched the flight of a launched booster on the surface of a smoked glass plate with a little stylus. As the stylus went through, it cut off the smoke; it projected a 3D image of the superimposed trace of one in one dimension and the other in the opposite dimension.

Air force Col. Thomas O. Haig, responsible for the ground station portion of the satellite command and control system, believed that 3D carried to the brain only about 2 percent of the information that X and Y did, making the new display system a useless tool for decision-making. When Haig arrived in Sunnyvale for a familiarization tour of the control center, the Fenski, Federick, and Miller technician had been trying to install the 3D system for almost a week. What he saw appalled him. The colonel talked to the technician, who thought the system would never function. Using his mechanical

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[58] U.S. Congress, Senate, Committee on Armed Services, Subcommittee on the Air Force, *Present and Planned Strength of the United States Air Force*, 20 June 1956, 2207-2214.

engineering background, Haig believed the 3D system "a monstrosity" that could never work. Haig went back to his office in El Segundo and wrote a memo instructing Lockheed to cancel the subcontract, recover all funds, and remove the equipment. When Gen. Schriever approved Haig's request, Lockheed knew Haig had arrived in the program. Although he had certainly saved the government "maybe, several hundred thousand to maybe a couple million [dollars]," by simplifying the satellite control center, he also made the control room functional instead of "a fancy, elaborate place. . . . They made it fancy enough, God knows, but at least we took that part out."[59] Despite the large amounts of money floating around AFBMD, and the reconnaissance satellite program's status as a national priority, officers still tried to save tax dollars.

The air force also had its share of unsavory characters that made cooperation difficult. When Philco employee Howie Althouse transferred to the station integration office at the New Boston Tracking Station in New Hampshire, he encountered some disagreeable officers. The contractors had cubicles in a building with an air force major and his staff who acted as the contract monitors. The major distrusted the contractors and listened in on their phone conversations with the home office, read company correspondence left in in-baskets, and stayed late every night. The contractors retaliated several times by leaving phony memos and noting the specific location where they had placed things the night before. After the major moved on, Althouse finally felt he could work without having to look over his shoulder.[60]

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[59] Haig interview by author.

[60] Howard Althouse, electronic mail to author, SUBJ: "BOSS," 18 Dec 2000.

At other times the whole unit, contractors and military, enjoyed station-wide picnics or ball games. At New Boston, a team effort in the conservation program won air force-wide awards for safeguarding the environment. In addition, over the years, a base-wide effort transformed some of the 2,800 acres into a recreational park for the military community in New England, not an easy task on the site of a former World War II B-24 Liberator practice bombing range. The military got the state to stock several ponds with trout and on the station they raised pheasants for hunting, made camping spots, allowed firewood cutting, and built a trap and skeet range. The contractors had access to all these recreational opportunities, too, but non-base personnel did not, angering some of the locals. Today, because of their efforts, the base provides a military recreation area as well as an air force satellite tracking station.[61]

Despite the unusually cooperative atmosphere, the situation began to look to some senior air force leaders like Lockheed had its hands full with development and testing of the Agena booster, the control center and all of the tracking sites, in addition to serving as prime contractor for the reconnaissance satellite program. To make matters easier, Lockheed contracted much of the tracking station work out to radio company Philco. Althouse, though, said that Lockheed and Philco got along "Like teenagers!"[62] In 1958, Philco and Lockheed made a gentlemen's agreement and started work. Shaking hands hurt Philco when it came time to staffing the first tracking stations. Philco thought it

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[61] Ibid. On the author's visit to New Boston in 1995, the station commander stated that anglers still could not drop anchor in the well-stocked Joe English Pond because of the risk of a detonation, a remnant of the base's former use as a World War II bombing range when the pond was a prime target.

[62] Ibid.

would get to staff all the remote tracking stations. When the air force awarded the contracts for the tracking stations individually, Lockheed got the prizes, Vandenberg and Hawaii, leaving Philco with the remote sites at Annette Island and Kodiak Island in Alaska, and the tracking ship *Joe E. Mann* in the Pacific Ocean (New Boston was not yet ready for operations personnel), considered less-than-first-class locations. Philco went ahead, though, and sought employees for these assignments because the company had people with a reputation for going to remote assignments and doing a good job without a lot of fuss.[63]

Even though the air force trusted Lockheed to get the job done, the Air Force Ballistic Missile Division believed that difficulties in the development of satellite command and control could soon overwhelm the contractor. Arnell ("Stormy") Sult, the Deputy Director of the Command, Communications and Control Directorate in Los Angeles, monitored the technical development and operation of the Satellite Test Center and the tracking stations. General Schriever, therefore, gave Sult the task of leading a team of officers to review the progress of development and operation of the control center and tracking stations.

By now, there were three separate satellite programs: MIDAS (missile warning), SENTRY (photoreconnaissance), and DISCOVERER (biomedical research cover story for the CORONA photoreconnaissance satellite). Concern about how the separate satellite programs should share in the expense of operating the Air Force Satellite Control Facility also entered into the picture. Sult's team spent three weeks visiting Lockheed

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[63] Ibid.; Dr. Walter B. LaBerge, telephone interview by author, tape recording, 11 Oct 2001.

and Philco, dissecting each contractor's duties and organization, and costing out the assets at each of the tracking stations. Armed with that information, Sult and his supervisor, Lt. Col. Gene Allison, assembled a formula based upon the average time each of the three types of satellites used the antennas during a support at the various tracking stations. This along with the value of the station assets determined how much each satellite program office should budget for use of the AFSCF. General Schriever called it the "Sult Formula."[64]

The satellite program offices agreed to the recommendations, although the MIDAS program office expressed unhappiness with the formula for deciding their share of the Air Force Satellite Control Facility operational costs. MIDAS, which orbited at fifteen hundred to two thousand miles, had the longest acquisition time by the tracking stations of any of the three programs, so under the formula had to budget the most for AFSCF support. Finally, with the three programs acquiescing, Sult wrote up a report of his findings and recommendations and briefed it to Schriever and his staff, making the following recommendations:

> 1. That Lockheed was overloaded and should be relieved of some of its responsibilities in the Air Force Satellite Control Facility.
> 2. That Lockheed should retain the Control Center development and operation.
> 3. That Lockheed should retain responsibility for manning and supporting the Vandenberg Tracking Station, inasmuch as it would also support the Thor/Agena launches from VAFB.
> 4. That Philco should become a Prime Contractor to be responsible for development, installation, manning and operation of the remaining and future tracking stations. Philco also had contract responsibility for some of the transmitters and receivers that were integrated into the Agena Space Vehicle.[65]

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[64] A. Stormy Sult, telephone interview by author, tape recording, 8 Sept. 2001.

[65] A. Stormy Sult, electronic mail to author, SUBJ: "Contractors," 29 Aug. 2001.

Schriever then asked Sult to brief Lockheed and Philco of the approved plan for splitting the satellite command and control pie. Lockheed sent a contingent to the Los Angeles headquarters for Sult's briefing. They listened attentively but obviously disagreed with what they heard. Afterwards, the Lockheed Program Director, Fred O'Green, met privately with Schriever, probably to try to persuade Schriever to overturn some of the recommendations. The recommendations went into effect. Philco successfully outbid Lockheed for the role of prime contractor and achieved a major rise in their status in the air force space program.[66] In addition, the status of Philco meant that the military's system of satellite command and control had now reached a new level of importance, worthy of its own prime contractor.

Friction between the contractors now increased with Philco's elevation to co-equal status with Lockheed. For example, Lockheed resisted Philco's attempt to increase the size of its effort; the two companies bickered and contested continuously, according to several former program officers. At the monthly "Black Saturday" sessions, where the contractors' representatives and the military program officials got together and went over all aspects of the programs for the previous month, everybody "lied like crazy." The "Black Saturday" sessions helped smooth relations between the contractors, kept the

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[66] Lockheed CORONA program chief James Plummer said in an electronic mail to the author that Philco outbid Lockheed "largely because of overhead rates," certainly likely given Lockheed's tendency to use professional engineers and Philco's use of electronics technicians, who were paid far less. (James W. Plummer, electronic mail to author, SUBJ: "Fw: dissertation," 4 Sept. 2001); LaBerge agreed in a telephone interview that giving the Air Force Satellite Control Facility its own contract was most likely a cost-saving move by the air force. For more on personnel issues, see Chapter 5.

control center a reasonable size, and helped straighten out a horrible computer mess.[67] The air force also kept the contractors in line by getting involved directly.

Although the contractors competed and certainly tried to protect their turf, they did not collude. When General King led the Air Force Satellite Control Facility, he wanted a better measurement of station performance, so he ordered records kept. He ordered the Field Test Force Director, the representative from the satellite's program office on duty while a satellite orbited, to write down a score for the stations during individual satellite support operations. They had a check sheet with a simple *Yes* or *No.* "Did the command message reach the station and the validation come back? Yes or no? Did the station come up on the satellite on time? Yes or no? Was the ephemeris data transmitted in? Yes or no?" Some officers worried the scoring system might ruin the morale of the stations. Ignoring them, King went forward, anyway, because he felt it important to know which stations could adequately support the satellites and which ones could not, and if he had to relieve somebody, he would have the information necessary to back it up. Resistance to the idea of comparing the stations against each other began with King's own vice commander and reached down into the stations, but the scores turned out as King expected. In King's estimation, the level of professionalism in the AFSCF meant he had to evaluate the stations' performance because the satellite program offices that had the use of stations had to know whether they could trust them or not. King thought that comparing the stations to their peers could improve service to the customers,

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[67] Haig interview by author.

the satellite programs.[68] The Air Force Satellite Control Facility's mission, after all, was service.

In sum, therefore, to help Air Force Ballistic Missile Division accomplish the important task of satellite command and control development, they assigned subprojects and problems to different types of professionals. AFBMD assigned the overall Advanced Reconnaissance System to Lockheed; Lockheed, in turn, farmed out many projects the airplane company did not have the expertise to handle on its own. As the satellite command and control system grew larger, Lockheed called in even more subcontractors to handle more of the contract. Finally, the air force stepped in and made the difficult decisions to replace Lockheed as prime contractor for the Air Force Satellite Control Facility. As times changed, and as air force officers grew in their knowledge and experience of space operations, the service Lockheed provided came to be less indispensable. In the late 1950s, though, Lockheed provided the air force a service it could not have developed on its own.

Constructing Test Environments

The inventors of the air force system of satellite command and control not only embodied the Air Force Satellite Control Facility with the political and economic characteristics it needed to survive in its environment, but engineers also constructed test environments that became successively more complex and more like the world that they believed the system would encounter once operational. Then, in response to an urgent

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[68] King interview by author.

request from Air Research and Development Command Headquarters for a test plan covering the IGY period, in January 1956 the Western Development Division issued a preliminary development plan for WS-117L's initial test phase.[69]

The initial test phase for the Advanced Reconnaissance System included the research, design, development, and provision of all components and subsystems for both an orbiting vehicle system and the necessary facilities for launching, acquisition, tracking, communications, and ground testing. The plan included ten orbital tests of the vehicle using the Atlas ICBM as a booster, beginning in August 1958 and launched at a rate of one a month for a total of ten vehicles, expecting six to reach orbit. The first two tests would be from the Eastern Test Range in Florida; the remainder from California.

Preliminary research studies indicated that the problem of signal acquisition had more to do with the space-to-ground link than the ground-to-space link. For acquisition and tracking, engineers planned to use the AN/FPS-16 instrumentation radar, still under construction. The entire AN/FPS-16 system, including the sixteen-foot parabolic reflector, the transmitter and the receiver, needed modification to pick up the relatively weak signals coming from space. Engineers confidently predicted that they could construct a receiver for the ground stations with adequate sensitivity and a spaceborne transmitter with adequate output power within the "state of the art."[70]

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[69] Maj. Gen. B. A. Schriever, "Foreword," in Western Development Division, *Weapon System 117L Preliminary Development Plan (Initial Test Phase)*, 14 Jan. 1956, i, AFHRA, K243.8636-39.

[70] Ibid., 9.

Because of the rush to get the program operational as soon as possible, the air force plan called for using as much off-the-shelf equipment as possible. Engineers, therefore, developed a ground-to-space command link and a space-to-ground telemetry link using techniques that had been around for some time and mostly recycled equipment. They understood receiving ICBM telemetry and transmitting information to ICBMs, such as commanding a missile to self-destruct when ground controllers saw it going awry. An incident that occurred at the New Boston tracking station during a critical command upload revealed the off-the-shelf nature of the WS-117L program. The station used a GE-125 punched-paper tape reader to send commands to orbiting satellites. Before a scheduled support, the optical reader failed when the light bulb that read the holes in the paper burned out. Joe Schraml, a station operator, made a call to logistics, which had no spare bulbs. Controllers informed the chief of operations, Alex Czernysz, that the station could not provide support because a bad bulb made the reader inoperative. When Czernysz looked at the burned-out bulb, he thought it looked familiar. He went outside, got the dome lamp bulb from his 1958 Mercedes 220S, and it fit the optical reader. With minutes to spare, New Boston completed the support with a foreign-made part.[71] The system engineers had successfully studied a variety of technical configurations meant to provide the best support with the least amount of difficulty in the fastest possible manner. Yet engineers and technicians did not just shove together off-the-shelf parts in the hopes that they could provide an adequate capability in a hurry. Engineers designed the remote

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[71] Joe Schraml, electronic mail to author, SUBJ: "Re: New Guestbook Entry!," 20 Aug. 2001; Alexander Czernysz, electronic mail to author, SUBJ: "New Boston Tracking Station," 24 Aug. 2001.

tracking station equipment systems to meet the requirements of a particular type of satellite--the early CORONA vehicles--and its particular instrumentation. They thought out and systematically designed the Air Force Satellite Control Facility to provide immediate support for important national security needs, rather than using the Advanced Reconnaissance System to advance the state-of-the-art in telemetry technology.

Engineers also studied several geographical configurations for the WS-117L tracking stations in order to determine the best arrangement for data acquisition needs. At this point, because the air force preferred data readout for retrieving intelligence pictures, not physically recovering the film from space as they eventually opted for, the stations required engineers take into account a number of considerations. Using "systems analysis," Lockheed engineers N. N. Berger, N. E. Tabor, and L. Lutzker performed an analysis of the accuracy requirements of the tracking network, revealing a need for better accuracy in angle determination for orbit predictions. In order to achieve adequate satellite acquisition on the first orbit, the tracking radar had to observe the satellite at an elevation angle of ten degrees or higher for at least two minutes. In order also to achieve data readout times long enough to retrieve all the intelligence data, a station in the northwest continental United States inadequately met their needs.[72]

In addition, all three tracking stations--small budgets limited the planned system to three operational stations--had to be in the United States or its possessions. Hawaii, a station planned for the test phase, could not completely serve operational needs because,

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[72] N. N. Berger, N. E. Tabor, and L. Lutzker, *WS 117L Criteria for Geographical Configuration of Data-Acquisition Stations*, 12 Aug 1957, Table III and Appendix A, DTIC, AD370463. Only the engineers' first two initials appear on the report.

although it could gather useful data for orbit prediction, its far southern location could not support long enough data readout times. In addition, in the event of hostilities, Oahu could be "susceptible to enemy attack, destruction, or even capture." In Oahu's favor, excellent supply and logistics--an important consideration--kept it in the running. Therefore, another consideration entered into the analysis: the sites had to be close to military airfields, railheads, and all-weather transportation facilities with water, telephone, power, and housing. Such thoughts made Pretoria, South Africa, a good location. Major Sult visited the proposed site, traveling on *Air Force 2* to get there, but it ultimately did not make the list because of security considerations. Nevertheless, remotely locating the stations introduced other factors to consider, such as dependents' living arrangements, length of duty tours, additional pay for undesirable locations, and difficulty in recruiting and retaining experienced personnel.[73] As they wrote the report, the planners added more and more requirements for the tracking station locations to meet.

In their considerations of tracking station locations, Berger, Tabor, and Lutzker also included a discussion of countermeasures the Soviets might take to prevent the United States from retrieving reconnaissance data from space. They considered electronic jamming of a sixty-foot antenna from thirty miles at sea or from fifty thousand feet impractical because of the power required and the size of a jamming antenna. Interference posed a more serious problem, though, because the jammer only required knowledge of the frequency the tracking station transmitted on, not a secret at all. Overall, the consequences of system compromise stood as a severe problem for

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[73] Ibid.; Sult interview by author.

consideration, because if the Soviets knew American capabilities from space, that information could provide the USSR with the information needed to effect countermeasures. To prevent national security compromises, the stations had to be farther than six hundred nautical miles from Soviet territory.[74] Another reason for the Alaskan and Hawaiian sites: the air force had no real idea how difficult it might be to get to orbit and Alaska could be the first place to pick up the satellite's ground track over American soil. These sites also proved invaluable to recovery of space capsules.[75] The tracking station in Alaska sent the command to eject the film capsule and then aircraft recovered the capsule over the Pacific Ocean in the area known as the "ballpark."

In addition, natural and human forms of interference could be just as problematic as Soviet-generated jamming. The site had to allow 360-degree radius search and acquisition at elevations of two degrees or higher, a separation of ten to fifteen miles between the tracking and data receiving antennas, and enough distance from major airfields to prevent interference similar to television flutter or "ghosting." They also had to be far enough from heavily populated urban or industrial areas to provide protection from interference from rotating machinery, radiating home radio and television receivers, and other devices. For example, human-made interference struck the weather satellite program during the Cuban Missile Crisis. On Monday, 29 October 1962, operators failed to read out data from a weather satellite over Eglin AFB, Florida, after a successful

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[74] Lockheed, *WS 117L Facilities Master Plan of 15 Mar 1957, Revision of 30 Sep 1957*, 30 Sept. 1957, III-1, DTIC, AD370425; Marv Sumner, electronic mail to author, SUBJ: "AFSCN History,"15 Dec. 1999.

[75] Frederic C. E. Oder, electronic mail to author, SUBJ: "Re: Early 117L," 5 Nov. 1999. Alaska achieved statehood on 3 Jan. 1959.

weekend of supports. They located the source of interference almost immediately: in order to command the satellite, they had to aim their transmitter almost directly across the housing area at Eglin. On Monday, traditionally washday, the continued use of washers, dryers, vacuum cleaners, and televisions transmitted a lot of interference emanating from the housing area. Weather satellite program manager Col. Tom Haig convinced Eglin's wing commander, Brig. Gen. A. T. Culbertson, to throw the power switch to base housing whenever a satellite neared the base. Later that week, Culbertson inserted information into the base news bulletin about periodic power outages, and the interference disappeared.[76] Turning the power off in base housing served a temporary situation like the Cuban Missile Crisis, but the air force had to locate permanent tracking stations to avoid this type of human-made interference.

Finally, with their analysis complete, Lockheed planned the Northwest Station in Alaska; Station Two anywhere in the Midwestern United States north of the center line of the nation; and Station Three anywhere in the Northeast United States north of the Mason-Dixon Line and sufficiently remote to prevent human-made interference. They settled on Annette Island, Alaska; Ottumwa, Iowa; and New Boston, New Hampshire. These locations, sufficiently remote to prevent human-made interference but not too remote to prevent adequate logistics, already had adequate supplies of power, water, and

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[76] Lockheed, *WS 117L Facilities Master Plan of 15 Mar 1957, Revision of 30 Sep 1957*, p. III-8; National Reconnaissance Office, *A History of Satellite Reconnaissance, Volume II*, 30 Sept. 1957, 251-2, AFSPC/HO.

housing, and made Soviet countermeasures more difficult.[77] Lockheed estimated the cost of each station at $10.967 million, including $4.977 million for facilities and $5.99 million in equipment, or over $32 million for the three tracking stations. The total WS-117L facilities estimate, including testing, tracking and launch facilities, came in at $112.7 million 1957 dollars.[78]

When considering the amount of equipment and personnel needed at each remote tracking station, the cost for each tracking station began to add up. In the earliest configuration of the Kodiak, Alaska, tracking station, for example, the system of command and control required two antennas, a VERLORT (Very Long Range Tracking) three-pulse tracking and commanding radar and a tri-helix telemetry-receiving antenna. In addition, there was a one hundred-word-per-minute teletype machine and analog voice, that is, the telephone, which provided the off-station communications. Teletype messages told the Kodiak operators the launch and support schedules, and then the operators passed telemetry readouts after each support back to Sunnyvale. Real-time telephone calls served adequately for everything else. The air force could encrypt the

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[77] Berger, Tabor, and Lutzker, *WS 117L Criteria for Geographical Configuration of Data-Acquisition Stations*, 12 Aug. 1957, Appendices C, E, and G, DTIC, AD370463.

[78] Lockheed, *WS 117L Facilities Master Plan of 15 Mar 1957, Revision of 30 Sep 1957*, Table II. $112.7 million 1957 dollars is about $716.37 million 2001 dollars. In 1968, well after the Air Force Satellite Control Facility was operational, the General Accounting Office concluded that the air force rushed the network into operation using the concurrency method, wasting millions of dollars by "prematurely procuring" the 60-foot antenna and other tracking systems. In particular, the GAO pointed out that the construction, teardown, and reconstruction of the Annette Island Tracking Station cost the government an extra $1.7 million. The air force agreed with the GAO and altered satellite program planning to allow for changes in launch schedules (in General Accounting Office, "Opportunities for Savings in Space Program by Reevaluating Needs before Buying Facilities: Department of the Air Force," B-164027, courtesy GAO).

teletype, but all voice transmissions went in the clear. Because a learning curve existed in the United States and the USSR, because the air force went to great lengths to publicize its space program, and because the air force could not hide these electronic secrets, eavesdropping was common. Marv Sumner reported from his days in Alaska that a Russian fishing trawler drifted thirteen miles east of Kodiak, "probably listening to all of our voice and commanding."[79] The VERLORT radar transmitted three pulses during each pulse of the spacecraft; a contact pulse, called a main-bang, a command pulse, and an execute pulse. In this form of analog commanding, the time-position of the middle pulse varied at a sinusoidal rate. Four tone frequencies went into space, transmitted in pairs for a possible list of six commands, and later expanded to fifteen commands. Digital commands had three discrete time slots, a slot each for "ones," "zeros," and "Ss". The Ss kept the system in sync and the radar power steady when the ones and zeros did not go out. Analog commanding instructions came to the station by real-time voice, and station operators inserted them into the transmission stream; digital commands arrived at the station on the teletype as punched-paper tape before the satellite support.

At Kodiak, the telemetry antenna and its equipment van sat on a hill away from the radar and teletype equipment (called T-Hill or "Readout-Ridge"). The radar automatically tracked the satellite in angles and measured range to deliver tracking data. The van had receivers, demodulators, tape recorders, decommutators, and displays for

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[79] Marv Sumner, electronic mail to author, SUBJ: "AFSCF," 15 Dec. 1999. Robert M. Siptrott, another Alaska veteran, confirmed in a telephone interview by the author on 29 May 2001, that the Russian trawlers sometimes left before a launch. When that happened, Siptrott picked up the phone and called the Vandenberg launch control center to ask if engineers had cancelled the launch. "How did you know?" the launch controllers wanted to know. "Our Russian fishing trawler just left," Siptrott replied.

processing the raw telemetry. A large X-Y plotter with preprinted maps for paper in the site control room displayed the tracking data. Controllers described the support progress over the telephone to California as the antenna moved, and then mailed the maps south daily. All data left T-Hill on the voice line or in the mailbag. After a satellite support, a technician wrapped and addressed the magnetic recording tapes, strip-chart recordings, and hand-written data sheets, and took them down the hill to the mailroom. The teletype operator hand-typed lists of special readouts for post-pass transmission. A third antenna, a single whip on the roof of the van, received an unmodulated RF carrier from the satellite at 216 MHz and measured the one-way Doppler data, printed out on a punched-paper tape, which a controller took to the teletype room and transmitted to California. Even this simple system could handle lots of information, although not quickly.

In California, Charles Murphy was the lone CIA officer in Palo Alto in charge of setting up the reconnaissance program. On active-duty with the air force but assigned to the CIA, he had been a B-36 Peacemaker navigator and a key role player in the development of the U-2 reconnaissance aircraft. Murphy figured out how to use the Advanced Reconnaissance System by determining the best time of day to launch to ensure adequate daylight in the USSR target area and what altitude to launch into to get the best pictures. Coordinating with analysts at the National Photo Interpretation Center, he learned about what scale meant to photointerpreters, how they liked to have targets illuminated, how much sun they needed, and the effect of shadows. People had thought about and been meeting these needs for a long time for aerial reconnaissance, but mission planning for satellites differed because the camera system, instead of flying a few

thousand feet in the air, orbited a hundred miles above the earth, making planning factors extremely different. Murphy eventually figured out the way that the intelligence community could use the CORONA camera: as a search system, not a spotting system. Eventually the photointerpreters discovered many of the targets of American nuclear weapons did not lie where the planners thought they did. In fact, in Murphy's opinion, the maps were bad enough that an American nuclear strike on the USSR might not have been successful. By himself, then, Murphy figured out launch windows and began turning the satellite program into a useful tool for gathering intelligence of the USSR.[80]

The Subsystem H engineers, using largely off-the-shelf equipment, managed to cobble together a satellite command and control system before the first reconnaissance launch, achieving successes and failures as often as any other aspect of the early reconnaissance program. With the test phase essentially over, the Air Force Satellite Control Facility prepared to expand its role in the air force space program.

Summary

One can clearly see the social construction of the Advanced Reconnaissance System in this intermediate phase. During the developmental stage, before the military's system of satellite command and control came into use, satellite command and control changed from a relatively simple idea into a complex system infused with various economic, political, and social factors. To help them accomplish the important task of supporting a complicated reconnaissance satellite program, the Air Force Ballistic

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[80] Col. Charles Murphy, USAF, Retired, telephone interview by author, tape recording, 26 Sept. 2001.

Missile Division and Lockheed called in subcontractors to handle more of the system's development. As the invention developed, the inventor-entrepreneurs and their associates embodied in their invention characteristics it needed to survive in the maze of government agencies. The Subsystem H engineers accelerated the development process by modifying off-the-shelf equipment to create a satellite command and control system ready before the first launch and absolutely necessary for the early reconnaissance program.

By the end of 1958, the tracking stations had been built, installed, checked out, and waited the first planned launch, set for early 1959. With the covert program established and because of the important critical need that the Advanced Reconnaissance System filled, the United States made the decision to get operational as soon as possible, rather than drag out testing the system. Therefore, the period of testing essentially ended as Air Force Satellite Control Facility engineers moved into developing the techniques necessary to support satellites critical to national security.

CHAPTER 3

"GETTING OFF DEAD CENTER": INNOVATING FOR A SINGLE CUSTOMER

> The instrumented earth satellite is one of the most exciting adventures in the Air Force research and development program.[1]
>
> -- U.S. Air Force Scientific Advisory Board, May 1956

> The money flowing in from the NRO and the CIA made satellite command and control work.[2]
>
> -- Brig. Gen. William G. King, Jr., USAF, Retired
> Former Commander, Air Force Satellite Control Facility

The first attempt to launch a reconnaissance satellite vehicle on board a Thor/Agena booster came on 21 January 1959. While the Thor booster quietly sat on the launch pad, the Agena upper stage malfunctioned when small, solid rockets that forced propellant into the rocket engine's fuel inlet prematurely fired. After inspection, the Agena turned out to be a total loss. People called this launch attempt DISCOVERER Ø.[3]

On 28 February 1959, the air force finally launched DISCOVERER I carrying only a light engineering payload. The Air Force Satellite Control Facility presumed it to have crashed near the South Pole, even though at least one tracking station claimed to

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[1] "Report of the Scientific Advisory Board Reconnaissance Panel on Reconnaissance from Satellite Vehicles," 28 May 1956, Dr. Carl F. J. Overhage, Chairman.

[2] King interview by author.

[3] Coolbaugh, "Genesis of the USAF's First Satellite Programme," 299. The air force refurbished and reused the Thor on a subsequent mission.

have heard it on orbit. DISCOVERER II, the first mission to reach orbit, failed when controllers lost it on the seventeenth orbit because a bad command sequence ejected the capsule at the wrong time, forcing reentry near Spitzbergen, Norway. Efforts to recover the capsule ended when aerial reconnaissance revealed the Soviets probably got the capsule, which carried a pair of mice, not a camera.[4] The first camera-carrying mission, DISCOVERER IV, failed to reach orbit when the Agena booster burned out prematurely. A string of failures followed when, for example, DISCOVERER V's camera batteries failed on orbit, the range safety officer blew up DISCOVERER X, or DISCOVERER XI's reentry vehicle ejected but the spin-stabilization rockets exploded during reentry. The first successful mission, DISCOVERER XIII, came in August 1960, a year and a half after the first launch. The very next mission, DISCOVERER XIV, included the first air-recovered film capsule, returning more imagery of the USSR than the twenty-four previous U-2 flights combined.[5]

True to the engineering culture of the day, James Plummer, Lockheed's CORONA program manager, looked on every launch as a successful test, whether or not it provided reconnaissance of the USSR: "We didn't look at those as twelve failures, we looked at those as twelve successes. We were learning new things every time in every part of the missile and the recovery and all of the things that we had to do. . . . If it hadn't been for President Eisenhower's support for the [program], of course it would have been

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[4] Day, *Eye in the Sky*, 52-3; Peebles, *Corona*, 66-7.

[5] Dwayne A. Day, "The Development and Improvement of the Satellite," in Day, *Eye in the Sky*, 52-62. DISCOVERER XIII, a diagnostic mission, did not carry a camera, but the water-recovered capsule carried an American flag.

cancelled."[6] DISCOVERER XIV, the first completely successful reconnaissance satellite mission start-to-finish, included an air catch of the capsule and processed reconnaissance information. CORONA continued to serve national reconnaissance needs until the 1970s.

Before these brilliant successes of the satellite program, the creators had to develop their invention into a complex system of manufacturing, sales, and service facilities. This chapter shows that engineers and managers created an essentially conservative invention--satellite command and control--out of a radical system--satellite-based reconnaissance. In its essence, the satellite command and control system developed for the Advanced Reconnaissance System simply improved conventional radar tracking and missile telemetry techniques. Those presiding over Subsystem H, the Air Force Ballistic Missile Division and Lockheed, tried to develop command and control as much as possible, essentially going beyond their original mandate. These system builders strove to increase the size of the system under their control, creating a satellite command and control system larger than the one originally envisioned for a single satellite program.[7] In addition, once innovation occurred, the inventor-entrepreneurs faded from the focal point of the activity into the background in favor of the new system, officially designated as the 6594th Test Wing (Satellite), with the single purpose of supporting the national intelligence program.

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[6] James W. Plummer, telephone interview by author, tape recording, 8 Sept. 2001.

[7] Hughes, "Evolution of Large Systems," 64-66.

Inside the air force, people viewed satellite-based reconnaissance as a radical proposal. Although satellite command and control evolved out of the radical idea of satellite-based strategic reconnaissance, it used older practices borrowed from the ICBM test environment, making it essentially a conservative idea. At the urging of the contractors and the air force, the size of the system began to expand. Those presiding over Subsystem H wanted to develop satellite command and control as much as possible. Standing in the way of Lockheed and the air force truly controlling the new satellite command and control system, numerous players added an ounce of their own control to the system. By 1961, managers, both contractors and military officers, had replaced the inventors of satellite command and control. After successfully arguing that a service organization should be responsible for command and control of the WS-117L program, not an operational nuclear command, the air force retained satellite command and control as a critical function for the Air Force test community to perform.

Expanding the Size of the System under Control

In the conservative mid-1950s, some in government viewed satellite-based reconnaissance as a radical invention too experimental and unproven for such an important national defense role. Yet no one viewed satellite command and control as anything especially difficult to accomplish because it used older techniques borrowed from the ICBM test environment. And because it was essential to the reconnaissance satellite mission, the air force developed satellite command and control as much as possible, and in the process, expanded the scope of the system under their control.

Despite the military unit designations, operations in Air Force Satellite Control Facility had a decidedly nonmilitary flavor to them. Geographically separated from each other, operations ran much more like a corporate undertaking than a military one. Newly arriving air force personnel wore civilian clothes so as to not stand out among the people entering and exiting the various Lockheed buildings. The air force even went so far as to issue a specific directive on proper civilian attire: "A business suit, shirt, and tie compose the normal attire worn by businessmen. The coat may be removed within the office of work. Female officers will follow accepted standards of business and professional women when wearing civilian clothing and accessories."[8] From this unquestionably nonmilitary start, the use of first names among the engineers became the mode of operation because a mixed group of military and contractors working side-by-side made up the Field Test Force in Sunnyvale. When controllers established the voice network for a satellite support, the test controller in Sunnyvale and the operations controller at the remote tracking station could be either military or a contractor.[9]

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[8] MEMO, Lt Col V. T. Ford, Office of the Special Assistant to the Secretary of Defense for Guided Missiles, SUBJ: "Military Personnel News Letter," 14 Sept. 1956, 6, AFHRA, 168.7171-157.

[9] To blur the command lines and eliminate military protocols, such as when captains in Sunnyvale gave directions to majors at tracking stations, the use of call signs came into practice. According to Keith R. Smith in an email to the author (SUBJ: "Re: AFSCF," 16 Nov. 2000), the test controller at Sunnyvale became DICE, a corruption of IDCC, Interim Development Control Center; COOK worked for the California tracking station (originally Cooke AFB until the Air Force renamed it in 1958 in honor of the Air Force's second Chief of Staff, Hoyt S. Vandenberg, who died from cancer in 1954, shortly after leaving office); BOSS developed for the New Hampshire station, located at New *Bos*ton Air Station; HULA obviously served the Hawaii tracking station, among many others. As already mentioned, the sites at Kodiak Island and Annette Island in Alaska, were KODI and ANNE, respectively. Today the Air Force Satellite Control Facility includes HAWK (the Schriever AFB control facility, formerly *Falcon* AFS) and

American leaders from Eisenhower on down wanted photography of the Eurasian landmass as soon as possible. Air force leaders like General Schriever believed that the advanced reconnaissance system could provide a significant boost to intelligence capabilities. In meetings between Air Research and Development Command, the Air Force Ballistic Missile Division (recently renamed from Western Development Division), and Strategic Air Command, officers agreed that the minimum essential capability to handle operational pictures from any research and development flights could be sped up by using the California launch facilities, the Satellite Test Center for operational satellite control, reading out the data at the New Boston and Vandenberg stations, and using the Air Recovery Service's force in the Pacific to recover film capsules ejected from space.[10]

Therefore, with the tracking equipment undergoing installation and a preliminary budget in hand, Schriever's team set about producing a development plan for WS-117L. The 14 January 1956 "Development Report" kept in mind the upcoming International Geophysical Year and reinforced the cover story that the air force had a satellite program for research and development, not operational reconnaissance. The Air Force Ballistic Missile Division tried to grab a piece of the space prestige pie. The development program answered a request from air force headquarters to present a possible development program for the initial test phase of the Advanced Reconnaissance System,

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DICE; PIKE (the Colorado Tracking Station at Schriever AFB and in the shadow of Pikes Peak): REEF (the Diego Garcia Tracking Station on a coral atoll in the Indian Ocean): GUAM (at Anderson AFB, Guam); LION (at RAF Fylingdales, United Kingdom); POGO (at Thule Air Base in northern Greenland); BOSS; and HULA.

[10] MEMO, Maj. Gen. James H. Walsh, Asst. Chief of Staff, Intelligence, SUBJ: SAMOS, to Secretary of the Air Force Dudley C. Sharp, Jr., 24 June 1960, AFHRA, K243.012-33.

which would permit the launching of an orbiting vehicle during the IGY.[11] In Schriever's cover letter to the development report, he made it clear that the Advanced Reconnaissance System made up part of the American IGY program. Later, he even suggested renaming WS-117L the "American Space Observatory," in celebration of the IGY, only barely concealing the satellite's real purpose.[12] Renaming never occurred, but AFBMD kept looking for ways to expand its role in the space program.

Lockheed's development reports over the next several months document its efforts to begin expanding the command and control system to make it useable by the time of the first launch, planned for late 1959. In March 1956, Lockheed produced its first report on the air force's PIED PIPER reconnaissance satellite. The reconnaissance satellite program consisted of a satellite vehicle containing equipment to perform visual, electronic, and infrared reconnaissance, together with the necessary system of ground stations and the data processing centers (the Satellite Test Center and the center planned for photointerpretation).[13] In April 1956, the air force followed up on Lockheed's work and submitted a "System Development Plan" for WS-117L. The plan called for a three hundred mile altitude, near-polar, circular orbit. An internal timer told the camera when to take pictures of "an area of interest." At this point in its development, designers

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[11] *Weapon System 117L Preliminary Development Plan (Initial Test Phase)*, 14 Jan. 1956, 1, AFHRA, K243.8636-38.

[12] Col. O. J. Ritland, Draft of "Preliminary Operational Concept of 117L," 28 July 1958, 5, AFHRA, K243.012-33.

[13] Lockheed Aircraft Corporation, Missile Systems Division, *Pied Piper Development Plan, Vol II Subsystem Plan, J. Vehicle Intercept and Control, Ground Station* (Van Nuys, Calif.), 1 March 1956, i, DTIC, AD370776.

planned WS-117L as a readout system, taking pictures over the USSR and transmitting them when over an American ground station.

Clearly there could be no reconnaissance satellite program without a command and control capability, and Lockheed used this requirement to increase the size of the system under the company's control. Lockheed planned a master computer for the "South Central Continental USA" WS-117L Intelligence Center, to be located presumably near Fort Worth, Texas, although the air force had not yet made a final decision on its location.[14] Lockheed expected "a nucleus of contractor personnel to provide a stable organizational structure with full exploitation of accumulated experience" would staff the center. Training of military and other contractor personnel could be accomplished there as well to provide more people to handle this "unique large-scale data handling system."[15] Already Lockheed was thinking ahead to the operational system.

Budget numbers also illustrate how the reconnaissance satellite program threatened to take over air force research and development. The WS-117L development plans estimated total cost at $74 million.[16] Total government research and development expenditures only reached $3.446 billion in 1956, so $74 million for WS-117L equaled 2

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[14] *WS-117L Advanced Reconnaissance System Development Plan*, 2 April 1956, B-10, AFHRA, K243.8636-39.

[15] Ibid., F-2.

[16] Ibid., G-1. This figure is $485.6 million 2001 dollars.

percent of that budget.[17] By 1959, the earliest date for which figures are available, defense department spending for space had only reached $489.5 million, but $74 million equaled 15 percent of the total space budget.[18] The AFBMD submitted a budget for the entire project at $95.5 million, including $13 million requested for the fourth quarter of FY 1956.[19] Schriever later recalled that he had a budget for WS-117L of $10 million in1957 dollars, a mere one-fifth of one percent then being spent on American government research and development, and just under 10 percent of what Lockheed said they needed to complete the project.[20] CIA Director Allen W. Dulles later authorized the release of just $7 million for Project CORONA in FY 1958. He intended the money for "covert procurement."[21] WS-117L, therefore, endangered a large portion of the total American research and development effort for space in the late 1950s, already a time of lean budgets and other national priorities.

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[17] McDougall, *...the Heavens and the Earth*, Appendix, "R&D Expenditures, 1927-1980: Data Points," 463.

[18] Stares, *The Militarization of Space*, Table 1, "Space Activities of the U.S. Government, 1959-1984," 255.

[19] *Weapon System 117L Preliminary Development Plan (Initial Test Phase)*, 3-1.

[20] Neufeld, ed., *Reflections on Research and Development in the United States Air Force*, 88; that figure is about $63.9 million in 2001 dollars. Source for total money spent on government R&D is McDougall, *...the Heavens and the Earth*, Appendix.

[21] MEMO, Allen W. Dulles, CIA Director, to the CIA Comptroller, SUBJ: Project CORONA, 25 April 1958, CORONA/ARGON/LANYARD Collection, National Reconnaissance Office Freedom of Information Act Office, Chantilly, VA, (hereafter NRO) 1/A/0001; MEMO, Richard M. Bissell, Jr., Special Assistant to the [CIA] Director for Planning and Development, to ARPA Director and Asst SecAF (R&D), SUBJ: Financing of Project CORONA, 25 June 1958, NRO 1/A/0003; MEMO, Geo. F. Kucera, Authorized DPD-DD/P Requester, SUBJ: "Program Approval," to Richard M. Bissell, Jr., Deputy CIA Director, and Allen W. Dulles, CIA Director, 18 Feb. 1959, NRO, 1/B/0087. Marked with Dulles's initials are the words: "Exact amount of overrun item to be subject to later approval."

Lockheed, primary contractor for the Advanced Reconnaissance System, did not let the numbers stop them as they proceeded with development. In fact, when Congress left budgets undecided, Lockheed continued work on the reconnaissance satellite program using company money until the air force resolved the situation.[22] Lockheed produced the next version of the WS-117L Development Plan in November 1956. They named themselves as the contractor for the "Vehicle Intercept, Control and Data Stations," tentatively selected for installation in the "Northeastern USA, Northwestern USA, South Central USA, and in the Hawaiian Islands." The report conceived of the four stations only in general terms. Each tracking station contained "tracking equipment, [an] orbit computer, [a] command transmitter, [a] recording system for reconnaissance data, and a telemeter-type receiving station."[23] The initial test phase included research, design, development, and provision of all the components and subsystems for both an orbiting vehicle system and facilities for launching, acquisition, tracking, communications, and ground tests. Command and control began to come to life, but only on paper.

Other innovations in space and missile design helped move the reconnaissance satellite program along even faster. Because of the army's work in the Jupiter missile program, and scientist Carl Gazley's work at RAND, ablative reentry techniques emerged on the satellite stage, proving both practical and, more important, lightweight. As physical recovery of data became an option, RAND Corporation scientists eagerly

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[22] Plummer interview by author.

[23] *WS-117L Advanced Reconnaissance System Development Plan*, 1 November 1956, Volume II *Subsystem Plans, J. Ground Support and Training*, 18.

introduced a new innovation to the air force--recoverable satellites. In a research memorandum entitled "A Family of Recoverable Reconnaissance Satellites," Merton Davies, Amrom Katz, and others, described a family of reconnaissance satellites that provided both an early and a continuing photographic reconnaissance capability to augment the WS-117L program. Davies and Katz had seen their ideas, first published in the late 1940s, go nowhere, especially not into space. The first proposed system included a water-recoverable vehicle, the basis for the CORONA program until the 1970s.[24] The air force now had important information necessary to bypass the problems they had in development of the data readout satellite.

The RAND report did not ignore the importance of command and control, either. R. T. Gabler wrote an appendix to "A Family of Recoverable Reconnaissance Satellites," called simply "Tracking." He included command and control for three main purposes: to determine an orbit accurate enough for photography; to command reentry of the capsule; and to establish the reentry area, suggesting two or three tracking sites, along a line normal to the orbit, spaced about 200 miles apart to allow a little orbital overlap and making orbit prediction more accurate. Three stations placed at a high northern latitude, if spaced about 200 miles down a longitudinal axis, met the necessary minimums to support the reconnaissance satellite program, which the air force already planned to launch into a polar orbit. The vehicle had to carry a transponder for ranging while on orbit and a radio beacon for locating it after splashdown. Gabler made suggestions about

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[24] M. E. Davies and A. H. Katz, et al., "A Family of Recoverable Reconnaissance Satellites," RAND Research Memorandum RM-2012, 12 Nov. 1957; Davies interview, 36; Augenstein interview, 32-33; Katz interview, 41.

frequencies, types of transponders to use, and tracking radars. He suggested using existing AN/FPS-16 tracking radars to command the satellite at 200 Hz and another antenna to receive from the satellite at 500 Hz. Total radio weight on-board the spacecraft would be between ten and fifteen pounds.[25] The RAND report left nothing out. Now the air force really only needed enough funding to make the project a reality.

Authorization finally came to accelerate WS-117L in late 1957. The AFBMD gave Lockheed approval to produce a development plan for program acceleration, which General Schriever approved on 5 December 1957. Robert Gross, Lockheed's program manager, told the air force "Lockheed would draw on its entire facility as necessary to expedite the WS-117L development." The Thor IRBM also became their choice as a booster over the not-yet-proven Atlas ICBM. In the most significant program change, Lockheed finally agreed to physical recovery of reconnaissance photographs from the orbiting vehicle rather than an electronic readout of scanned pictures on a video link, finally accepting RAND's capsule recovery proposal of November 1957. Lockheed wanted immediate authorization to proceed and provided the necessary hardware and services the air force typically provided its contractors. They expected the air force to expedite approval of subcontracts, given that the president had established the highest developmental priority for WS 117L, called "DX priority," which gave WS-117L the same national urgency as the ICBM.[26] Since WS-117L had a new lease on life,

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[25] R. T. Gabler, Appendix G, "Tracking," in "A Family of Recoverable Satellites," 12 Nov. 1957, 99-101.

[26] "Introduction," *Weapon System 117L Development Plan for Program Acceleration*, 5 Jan. 1958, AFHRA, K243.8636-41; MEMO, Col. F. C. E. Oder, Assistant for WS 117L, to Col. Terhune, Western Development Division Deputy Commander for

Lockheed asked that the air force waive military specifications for drawings in connection with Philco-supplied equipment. Instead, they would use "specifications in accordance with good commercial practice." They also asked for the authority to proceed immediately from design to fabrication, of ground support equipment, without air force design approval. Finally, Lockheed asked the air force to provide concrete foundations for the TLM-18 antennas at the interim tracking stations, or else to furnish authority for Lockheed to procure them directly from the antenna subcontractor.[27]

Location requirements for the ground stations now changed because of the RAND-proposed capsule recovery plan. Alaska entered the picture, as did California's central coast, while "Northeastern USA, Northwestern USA, [and] South Central USA," all departed. For the tracking function alone, especially on a first orbit, a near-polar location had the most advantages. About sixty-five degrees north latitude in Alaska, as RAND had previously determined, also had advantages as the best point to initiate recovery, which could then be fifteen hundred miles south. Hawaii remained in the picture because of the choice of the Pacific for the recovery zone.[28] The program began to expand even faster.

As a result of program acceleration, total cost for WS-117L ballooned to $95.1 million, an increase of almost 25 percent. Subsystem H, the largest chunk of the program, gobbled up $24.6 million, in part because it required a lot of people-supporting

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Weapon Systems, SUBJ: "R-W [Ramo-Wooldridge] participation in WS 117L," 14 Feb. 1958, AFHRA, K243.012-36.

[27] *Weapon System 117L Development Plan for Program Acceleration*, 5 Jan. 1958, para 1.3.1, AFHRA, K243.8636-41.

[28] Ibid., para. 2.4.

structures in places the government did not already own buildings. Lockheed convinced the air force that "the vital national importance of successful acceleration of the WS-117L program, and the inherent developmental difficulties associated with this complex Weapon System" justified the increase.[29] The new program expansion gave Lockheed another opportunity to expand the scope of the program under its control a little further.

The air force planned for construction on the tracking stations to begin in May 1958 because they needed the capability by November 1958 for the start of launch rehearsals. In April 1958, Schriever signed the first monthly status report for WS-117L, announcing the first test of the Advanced Reconnaissance System would take place in late 1959 from Cooke AFB on board a Thor IRBM. It also stated that the system now required five acquisition and tracking stations, probably located at Cooke; near Oxnard, California, downrange from the Cooke launch site; Kaena Point, Hawaii; Anchorage; and Sitka, Alaska. The interim facilities consisted of one sixty-foot diameter TLM-18 telemetry antenna and a receiver building, a tracking radar, and "associated structures." Van-mounted tracking and transmission facilities could be supplied for the stations in Alaska by November.

Development continued as the program received a new name. In the May 1958 status report, General Schriever reported that the Advanced Research Projects Agency, nominally responsible for all military space projects, had renamed the video reconnaissance portion of the Advanced Reconnaissance System vehicle "SENTRY." SENTRY now only referred to the video reconnaissance portion WS-117L, not the

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[29] Ibid., para. 1.3.

recoverable portion, which had already become the highly covert CORONA program. The new name did not refer to the biomedical satellites of the DISCOVERER program, which was just a CORONA cover story anyway, or to the plans for an infrared ICBM detection satellite. Schriever also reported that the contractors had the Cooke and Hawaii tracking stations on schedule for a 1 September 1958 completion. The air force agreed to the two sites in Alaska because of uncertainty about how accurate they could get the CORONA orbits.[30]

The June 1958 status report offered encouraging news, including some important shifts in program development. General Schriever reported that the Air Force Ballistic Missile Division had formed an Air Force Bioastronautics Division in California to function as a consultant and liaison group for all biomedical activity in the Advanced Reconnaissance Satellite program. This action reaffirmed the DISCOVERER cover story of a biomedical test program.[31] General Schriever also reported that the air force had decided to recover capsules returning from space by using Fairchild C-119 Flying Boxcars at approximately ten thousand feet. Just as significant, engineers described their progress on the ground equipment as it rapidly approached the prototype stage. By using printed circuits, they had managed to save a lot of development time. They also explained the techniques they intended to use to command the initial "call-down" of the capsule for recovery.

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[30] *Weapon System 117L Program Status Report*, 10 June 1958, AFHRA K243.012-36; Howie Althouse, electronic mail to author, SUBJ: "Re: AFSCF," 18 Nov. 2000; Oder interview by author.

[31] LTR, Roy Johnson, ARPA Director, to Richard Bissell, CIA, No SUBJ, 13 Aug. 1958, NRO, 1/A/0004.

In addition, the northeast control site had been selected for New Boston, New Hampshire, with the site still to be determined for the central United States. Construction began at the other sites. Finally, Lockheed also completed the design of the Interim Development Control Center in Palo Alto, California (later called the Satellite Test Center), although the location for the Central Intelligence Center remained "unresolved."[32] The locations for the Advanced Reconnaissance System Intelligence Center had moved to Strategic Air Command Headquarters at Offutt AFB, near Omaha, Nebraska, but the CIA objected to the decision. The air force envisioned SAC as the primary intelligence information user and operator of the Advanced Reconnaissance System satellites, so the location made sense.[33] Satisfied with Omaha as the choice for the operations center, ARPA Director Roy Johnson, manager of the overall military space program, wanted ARDC to run the satellite program, not SAC.[34]

On 1 July 1958, AFBMD published a new development plan for WS-117L with the title "New Horizons." Less than a year after formal program approval, the air force completed "beneficial occupancy" of WS-117L interim telemetry tracking facilities at Cooke, Kaena Point, Annette Island, and Kodiak Island. The New Hampshire site suffered from a lack of funding; when the money finally arrived, system integrators did not have enough time left in the relatively short northern construction season to complete

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[32] *Weapon System 117L Program Status Report*, 8 July 1958, AFHRA, K243.012-36.

[33] *Weapon System 117L Program Status Report*, 23 April 1958, AFHRA, K243.012-36.

[34] MEMO, Roy Johnson, ARPA Director, to Secretary of the Air Force Douglas, SUBJ: "WS-117L Program," 4 Dec. 1958, NRO, 1/A/0012.

the facility.[35] But by the end of 1958, the interim tracking stations had been built, installed, and checked out, and crews anxiously awaited the first planned launch of DISCOVERER I, set for late 1958.

Interested groups extended beyond contractors. Instead of bestowing the space budget on the air force, President Eisenhower created the Advanced Research Projects Agency (ARPA) to prevent any one military service from monopolizing the money. He ordered ARPA to manage and direct selected basic and applied research and development projects for the Department of Defense. Eisenhower directed ARPA to focus on high-risk technology that offered the potential for a dramatic advance for traditional military roles and missions. PIED PIPER certainly fit into both those categories. Secretary of Defense Neil H. McElroy formed ARPA on 8 February 1958 as a new agency for space technology research and development with complete authority for directing the expanding American military space program. Advanced Research Projects Agency Director Roy W. Johnson construed his mandate mission very broadly, considering his organization to be a "fourth military service," in effect a Military Space Agency.[36] In the area of space systems other than launch vehicles, the DoD's Research and Development Board had assigned military satellites to the air force in 1950. Now, with the creation of the new agency in 1958, program direction came from ARPA, not the air force or the ARDC in Ohio.

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[35] *SENTRY Program Status Report*, 10 Dec. 1958, AFHRA, K243.012-36.

[36] Roy W. Johnson, Director, Advanced Research Projects Agency, in *Astronautics and Space Exploration*, Hearings before the Select Committee on Astronautics and Space Exploration, 85th Cong., 2d Sess. (Washington: Government Printing Office, 1958), 1171.

In October 1958, in an effort to minimize the aggressive implications of the military participating in the national space program, ARPA director Johnson directed the air force to cease using the term "weapon system" when referring to satellite programs. The IGY showcased the scientific uses of a satellites, he reasoned, and using the term "weapon system" for a satellite program, even a reconnaissance satellite program, could stir up unnecessary commentary. Such actions by ARPA made the air force fearful that the agency might take over its space program.[37]

Air force fears, however, were unfounded. Defense Secretary McElroy gave ARPA responsibility for all American space programs, military and civilian, but the Air Force Ballistic Missile Division (AFBMD) in Los Angeles remained the executing agency for air force space programs. Program direction came from ARPA for the next year and a half, but in fact, the air force retained overall control of the reconnaissance satellite program; one more layer of bureaucracy stood between the air force and the defense establishment. So, although it appeared from the outside as if ARPA had taken over the air force's space program, the agency did little beyond supervising a few space studies, choosing instead to reassign most former air force space projects to air force field units such as the AFBMD. Even so, ARPA had a short-lived political role in advanced satellite reconnaissance because of the creation of a new, separate civilian agency responsible for space.

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[37] B. W. Augenstein, "Evolution of the U.S. Military Space Program, 1945-1960: Some Key Events in Study, Planning, and Program Development" (Santa Monica, CA: RAND Corporation, P-6814, 1982), 13.

Upon the recommendation of his Science Advisory Committee, chaired by James R. Killian, President Eisenhower submitted legislation to Congress and signed into law the National Aeronautics and Space Act of 1958, creating the National Aeronautics and Space Administration. In the realm of space exploration, NASA inherited existing scientific satellites and planetary missions from the National Science Foundation and ARPA, and later manned spaceflight as well. The National Aeronautics and Space Act divided American space activities between the public NASA civilian world and the more secretive military world.

Finally, ARPA lost its dominant role in December 1959 when the defense department divided the responsibility for the various military satellite missions among all three services, redesignating the fledgling military space agency solely as a research and development agency. On 6 March 1961, new Secretary of Defense Robert S. McNamara reversed direction further by assigning research, test, development, and engineering for all military space programs--satellites as well as launch vehicles--back to the air force, except for "unusual circumstances." Any DoD agency could conduct preliminary research. McNamara also stipulated that the services had to submit proposals for space development programs to the director of Defense Research and Engineering (DDR&E).[38] McNamara assigned the army responsibility for developing communications satellites; the navy responsibility for navigation satellites (primarily the Transit satellite navigation program); and the air force responsibility for reconnaissance and surveillance satellites. ARPA officially released WS-117L to the air force, but in reality the operational

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[38] Spires, *Beyond Horizons*, 56-95.

reconnaissance satellite program had already been reassigned to another secret DoD agency.[39]

More significant for this study of air force satellite command and control, President Eisenhower authorized the creation of an agency whose very existence remained secret until 1992. Deeming overhead reconnaissance too important to leave to the generals, on 31 August 1960, the defense department had created the Office of Missile and Space Systems under Assistant Secretary of the Air Force Joseph P. Charyk, who reported directly to the secretary of defense. In January 1961, DoD and the Central Intelligence Agency (CIA) jointly rechartered the organization and renamed it the National Reconnaissance Office, classifying its existence. NRO was a separate agency responsible for consolidation of all DoD "satellite and air vehicle overflight projects for intelligence," and "for the complete management and conduct" of these programs, thus fitting the American space program into its top-down Cold War paradigm.[40] The NRO developed techniques of procurement and program management, which the CIA dominated and which frequently involved over-spending. The NRO also took a share of the military space program, taking a huge bite out of total space activity and shrinking the

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[39] Augenstein, "Evolution of the U.S. Miltary Space Program," 15.

[40] Cyrus Vance, Deputy Secretary of Defense, Department of Defense Directive Number TS 5105.23, "National Reconnaissance Office," 27 March 1964, in *Exploring the Unknown*, vol. 1, 373-74. With the exception of this directive, the defense department prohibited using the terms National Reconnaissance Office, National Reconnaissance Program, or NRO in any document. Any reference had to use the phrase "Matters under the purview of DoD TS-5105.23."

amount of space work under "normal" military development procedures and control.[41] The NRO also assumed operational authority for overhead reconnaissance while also being designated the prime customer for all overhead intelligence, taking away the air force's authority for operating the nation's reconnaissance satellites. The air force refocused space activities only on launching and tracking satellites, not on their final product. For that, whether the nation knew about it or not, the NRO had primary responsibility.

The American space program now had three branches, one concerned primarily with space science (NASA), one concerned primarily with military support missions (the defense department), and one concerned primarily with reconnaissance operations (the National Reconnaissance Office). Later presidents and secretaries of defense formally endorsed these divisions, which remain largely in effect today.

Even though the program appeared on track for a 1959 launch, some intimately involved with the program wanted to make sure that it did not get off track, even slightly. Dr. Edwin (Din) Land, Chairman of the Scientific Advisory Board Reconnaissance Panel on Reconnaissance from Satellite Vehicles and inventor of the Polaroid instant film developing process, ran a meeting of the air force's Scientific Advisory Board panel on reconnaissance satellites, held in Boston near the CORONA camera maker, ITEK, in October 1958. ARPA Director Roy Johnson and Lockheed's CORONA program manager James Plummer both attended. Lockheed began the meeting by giving a

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[41] John L. McLucas, "The U.S. Space Program Since 1961: A Personal Assessment," in R. Cargill Hall and Jacob Neufeld, eds., *The U.S. Air Force in Space: 1945 to the 21st Century* (Washington, DC: USAF History and Museums Program, 1998), 85-87.

complete update on the CORONA program, receiving favorable reviews from those present. Land stated to all present, although clearly aimed at ARPA's Johnson, that the goals for CORONA included an operational system designed to achieve limited objectives--photoreconnaissance of the USSR--and that no one should tinker with the program like their own "pet R&D project." Land felt that the program should be governed by its security and cover requirements--the DISCOVERER biomedical story--to prevent exposure of the program. Johnson objected and suggested slipping CORONA into fall 1960 in order to speed along the process of developing the SENTRY program, what one officer present referred to as "super-CORONA." Land stated his view that simultaneous development of SENTRY interfered with developing CORONA into an operational system.[42]

ARPA objected to the time required to develop a new satellite program because Johnson saw Lockheed and the Air Force Ballistic Missile Division as in too much of a hurry. ARPA *authorized* the air force $136 million in FY 1958, representing only 63 percent of the requested $215 million, but initially only *released* $22.7 million on 20 June 1958, increasing that amount to a slightly larger $30.7 million in mid-July. General Schriever asked the air force to release another $40 million in late July (for a total of $70.7 million) but Secretary of the Air Force Douglas only released half that amount. Schriever asked for $20 million more in August 1958, which he did get. The total FY 1959 funding, planned at $136.2 million, dealt only with a trickle of funds. Schriever

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[42] MEMO, Col. William A. Sheppard, SUBJ: "Status of Scientific Advisory Committee for Reconnaissance Satellites," to General Schriever, 17 Nov. 1958, AFHRA, K243.012-36.

informed Douglas that a work stoppage might occur on WS-117L if Lockheed did not receive funding by 20 January 1959. Douglas then reduced funding for the overall program again, from $148.2 million to $96.6 million, excluding facilities, which he cut by $800,000. He tentatively planned FY 1960 funding at $148.0 million, but only for SENTRY and DISCOVERER because ARPA declared MIDAS separate from the other two. Schriever funded MIDAS on a month-to-month basis with mostly AFBMD funds, so work continued on it for the time being. Even given these relatively large sums of money, Johnson did not authorize the air force to begin operational development of the WS-117L program.[43]

Despite the apparent setback, the air force scheduled the first launch attempt for December 1958 as the system began to come together. The complete ground communications links between the tracking stations and the Palo Alto control center underwent a series of test to ensure their operational readiness. The air force and Lockheed had a simple test objective for the first flight, primarily to prove that the booster and the ground support equipment worked, as well as to check out the telemetry, tracking and control equipment. Other objectives included testing the interstation communications network and crew proficiency with the new equipment and procedures. This first launch attempt would be the air force's first operational experience with

[43] MSG, Gen. Schriever, Commander, AFBMD, to Secretary of the Air Force Douglas, no subj, 28 Feb. 1959, AFHRA, K243.012-36; MSG, Secretary of the Air Force Douglas to Gen. Schriever, no subj, 27 Feb. 1960, AFHRA, K243.012-36. This initial $136 million figure is $840,000,000 in 2001 dollars. The 1960 figure would be approximately $892.5 million in 2001 dollars. DoD's budget that year was nearly $48 billion ($283.7 billion 2001 dollars).

satellite command and control.[44] Even NASA's brief experience with the Explorer program did not compare to the ambition of the Air Force's first CORONA launch but the first attempt to launch a CORONA heralded bad tidings to come.

At this early stage in national space policy development, some Eisenhower administration officials saw satellite reconnaissance as contrary to the peaceful purposes dictate because satellite overflight of foreign territory might violate international law, as the U-2 program had. The government assured the reconnaissance satellite program's security, which it considered of the "utmose [sic] importance from the political standpoint, " through the CIA's actual responsibility for the program. Because any changes to the program would have to come from the president, any recommendation the air force made to take over the program completely would "have to be of sufficient importance to have the President change his mind," which the CIA did not deem likely to occur. Disagreeing with the CIA's position, the air force planned aggressively for exploitation of the imagery and to "request complete control of the program [from the CIA] following any relaxation of the security policy."[45] Although no relaxation of the security policy would come until the 1990s, the air force successfully made its point well known that only it provided a satellite command and control capability for national defense.

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[44] *SENTRY Program Status Report*, 10 Dec. 1958, AFHRA, K243.012-36.

[45] MEMO, SUBJ: Facts Concerning the Pro's and Con's of Air Force Control over Project CORONA, 15 May 1959, NRO, 1/C/0002.

ARPA used the new secrecy surrounding the military satellite programs to expand the scope of its control over WS-117L at the expense of the air force.[46] When the air force asked ARPA to declassify certain aspects of WS-117L, Johnson denied the request. He knew the air force wanted to publicize its space program and that Lockheed even had a publicity program ready to go to advertise its participation in WS-117L. After discussions with the state department, Johnson ordered that the air force and its contractors to make no further reference to WS-117L, reconnaissance satellites, or even the "launching of very large satellites."[47] The state department had concerns that publicity about reconnaissance satellites could disturb the general question of the international political framework in which the United States would place reconnaissance satellite programs. The National Security Council also still had that subject under consideration. Still trying to make its case as the nation's space service, the air force generally ignored Johnson's order to keep quiet and continued to give great publicity to its space activities and plans with press releases and magazine articles.[48] The publicity

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[46] MSG, Secretary of the Air Force Douglas to General Schriever, no subj, 5 Feb. 1959, AFHRA, K243.012-36.

[47] MEMO, Roy Johnson, Director of ARPA, to Secretary of the Air Force Douglas, SUBJ: "Classification of Information on WS-117L," 19 May 1959, AFHRA, K243.012-36.

[48] See, for example, Edison T. Blair, "From Saddles to Satellites," *The Airman* 5 (February 1961): 7-19; Larry Booda, "First Capsule Recovered from Satellite," *Space Technology* 3 (Oct. 1960): 41-43; Frank J. Clifford, "Discoverer--Trailblazer to Space," *The Airman* 5 (June 1961): 12-19; John Nammack, "C-119's Third Pass Snares Discoverer," *Space Technology* 3 (Oct. 1960): 44-45; Clarke Newlon, "Air Force Satellite Program Gets New Boss," *Missiles and Rockets* (5 Sept. 1960): 18; Bernard A. Schriever, "The Operational Urgency of R&D," *Air University Quarterly Review* 13 (Winter-Spring 1960): 235; Charles H.Terhune, Jr., "In the '*Soaring Sixties*' Man is on His Way--Up," *Air Force/Space Digest* (April 1960): 64-71; Thomas D. White, "At the Dawn of the Space Age," *Air Power Historian* 5 (Jan. 1958): 15-19; Joseph Kaplan,

program eventually so upset President Kennedy that, according to one staffer, apparently "every time the Air Force put up a space shot and any publicity was given to it, he just went through the roof."[49] Given the growing importance of space and satellites to the entire defense department, every interested group tried to look like it had a role to play.

ARPA tried to reduce the scope of other agency's involvement by introducing a new level of secrecy to the military space program, which the air force did not want. After the dramatic recovery of DISCOVERER XIII, General Schriever met President Eisenhower to show off the reentry vehicle, the first object recovered from outer space. The bucket contained nothing other than an American flag because of the diagnostic nature of the mission, but ARPA officials closed the doors and sealed up the room to prevent too many details about the mission from "leaking out."[50] This action upset General Schriever because it restricted publicity about this first air force success after a string of thirteen failures. Schriever became more upset following the next DISCOVERER mission one week later. "I didn't know that they had a camera on

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"How Man-made Satellites Can Affect Our Lives," *National Geographic* 132 (Dec 1957): 791-808.

[49] Solis Horowitz, advisor to the president, oral history, John F. Kennedy Library, in Stares, *The Militarization of Space*, 64; see also: George C. Wilson, "U.S. Is Formulating New Space Policy?," *Aviation Week and Space Technology* (18 June 1962): 26-27.

[50] For published newspaper accounts of the mission success, see, for example, Richard Witkin, "Washington to Hail Retrieved Capsule in Ceremony Today," *New York Times*, 13 Aug. 1960; "Air Force Shows Prize Capsule, *New York Times*, 14 Aug. 1960; Felix Belair, Jr., "Eisenhower is Given Flag That Orbited the Earth," *New York Times*, 16 Aug. 1960.

DISCOVERER XIV. Here I was, standing around, four-stars, giving them all the support," but ARPA officials neglected to tell Schriever the details of the mission.[51]

Already people thought about laying plans for a common-user satellite command and control network in the department of defense with the Air Force Satellite Control Facility at the core. ARPA planned to use the DISCOVERER tracking facilities in support of all other space programs. Total overall cost for FY 1960 stood at $64.1 million. In an effort to reduce costs, the defense department and NASA, the nation's other operators of a satellite command and control network, tried to come up with a satellite command and control system that would work for both of them. Secretary of Defense McElroy and NASA Administrator T. Keith Glennan agreed that they would pool their resources and effect cost savings by carefully coordinating the requirements of all potential users of a tracking and data acquisition system. The entire network would not be built at once, only common parts necessary for research and development, although eventually DoD and NASA expected to go their own ways as each matured and became more sophisticated.

To increase the likelihood of cooperation, DoD and NASA agreed to global tracking, data acquisition, communications, and data centers for space flight. They recognized that NASA's requirements primarily supported research and development flights whereas the military requirements supported both research and development as well as operational flights and intelligence-gathering. The two agencies agreed to share use of facilities, including the Goldstone facilities, and NASA sites in Africa, Australia,

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[51] Schriever interview by author. Schriever was commander of Air Research and Development Command at the time.

Spain, and Japan. The NASA Vanguard center would also share data freely with the Air Force Spacetrack facility at the Cambridge Research Center in Massachusetts. They also agreed to share worldwide communications networks. They would monitor developments by hosting a technical committee for continuing study of the global tracking, data acquisition, and communications problems.[52] At the 13 May 1959 meeting of the National Security Council, President Eisenhower gave priority "above all others for research and development and for achieving operational capability" to space programs having "key political, scientific, psychological or military import," including the "DISCOVERER (satellite guidance and recovery)" program.[53] Everyone, including the president himself, now understood the importance of satellite command and control for the national space effort.

In summary, then, the Air Force Ballistic Missile Division and Lockheed, presiding over Subsystem H, developed satellite command and control as much as possible in order to expand its role in the reconnaissance satellite program. In their haste to get the system operational, AFBMD and Lockheed methods included cutting corners on paperwork; switching to recovery from readout; using older equipment; and having the air force do as much of the legwork for Lockheed as possible. Lockheed and the air force, trying to control the new satellite command and control system on their own, dealt with other agencies, each attempting to take over part of the system. The Advanced

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[52] National Aeronautics and Space Administration and Department of Defense, "A National Program to Meet Satellite and Space Vehicle Tracking and Surveillance Requirements for FY 1959 and 1960," NSCA 1859, 19 Jan. 1959, in *Minutes of Meetings of the National Security Council*, A:III:0403.

[53] National Security Council 6021, 14 Dec. 1960, "Missiles and Military Space Programs," in *Minutes of Meetings of the National Security Council*, B:V:0211.

Research Projects Agency, obviously interested in expanding the scope of its control, used such methods as budgetary gimmicks and satellite program renaming regimens, as well as other attempts at asserting institutional control over the WS-117L program. Yet, always in the background, the CIA pressed to get CORONA operational as soon as possible, pushing the developers along the path to a satellite command and control system capable of supporting its reconnaissance satellite.

Manager-entrepreneurs take control from inventors

While the air force tried to increase the size of the military space program under its control, the Air Force Ballistic Missile Division dealt with a movement within the air force to bring WS-117L to operational status as soon as possible by turning it over to an operational command, namely Strategic Air Command. AFBMD felt that an operational program conducted concurrently with a developmental program would unnecessarily divert resources from the research and development program and thus prevent the timely delivery of a fully developed system. If the air force needed additional satellites, facilities, or other provisions for some operational or training reason, it might extend the research and development program perhaps unnecessarily.[54] As a result, manager-entrepreneurs, both contractors and military officers, started to replace the inventors of satellite command and control, who began to fade from the focal point of activity.

Some in the Air Force Ballistic Missile Division such as Col. Osmond Ritland, its deputy commander, believed that operation of the reconnaissance satellites by a combat

[54] MSG, Col. O. J. Ritland, no subj, to Chief of Staff, Gen. Thomas D. White, 23 July 1958, AFHRA, K243.012-36.

command, especially the all-nuclear SAC, might unnecessarily and unwarrantedly restrict the use of the product, overhead images of the USSR. The organization and operation of WS-117L in that framework, some worried, might lead to the exclusion of many desirable applications for a satellite system other than the collection of military intelligence. While the United States had a real, urgent, and lasting requirement for photoreconnaissance of the USSR, and while a satellite system could aid in the fulfillment of this requirement, WS-117L did not have to gather military intelligence, he argued. The system could perform other missions besides gather intelligence. An agency with a wider scope of understanding could use WS-117L to collect electronic, photographic, or visual data. In that case, the interpretation of the data would decide its final use. If a command such as SAC operated the system, the command's requirements--in this case, targets for nuclear weapons carried by bombers and missiles--would always come first and might come at the exclusion of other interests, such as those of the CIA, Atomic Energy Commission, industry, the scientific community, or the United Nations. The United States could also find systems such as WS-117L useful tools for transmitting radio or television signals for propaganda purposes, collecting weather information by observing worldwide cloud cover, tracking hurricanes or icebergs, supporting global navigation, collecting data from airbursts of nuclear weapons, providing scientific and technical information, or providing comprehensive worldwide mapping.[55]

Colonel Ritland recommended, therefore, that a service agency such as the Air Force Ballistic Missile Division should control the system to ensure that a single

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[55] Col. O. J. Ritland, Draft of "Preliminary Operational Concept of 117L," 28 July 1958, 1-2, AFHRA, K243.012-36.

organization without a combat mission could meet the requirements of all agencies. The organization involved in the gathering, transmitting, and receiving of the data, independent of the interpretation and use of the data, he felt, would be better able to support WS-117L. Ritland wanted to have one overall operating agency because the ground components of the system consisted of the greatest investment in dollars, research, and industrial personnel, and would therefore be the most expensive part of the system for another satellite program to duplicate. And because one set of data collected could be of use to several information consumers, Col. Ritland also believed a single service agency like AFBMD could serve many other agencies.[56] Ritland's suggestion that the air force create a service organization, which could fully and expeditiously exploit the potential of WS-117L, provided flexibility for future American positions on space sovereignty, without being subordinated to an organization having an overpowering mission requiring single-minded purpose and application of resources.[57] The dynamic nature of the forces that operate in space distinguished the medium as unique. With the research and development community involved in the operational side as well, they could be constantly on the alert for novel programs and original techniques to take full advantage of the new opportunities, which space operations offered.[58] To the inventors of the satellite command and control system, staying involved in its development and operation seemed to be paramount.

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[56] Ibid., 3-4.

[57] Ibid., 6.

[58] Gen. Schriever, "The Operational Urgency of R&D," 235.

Ritland also borrowed from the state department the argument that operation of WS-117L by SAC might "embarrass the United States in future international negotiations concerned with space sovereignty." America's declared space policy called for peaceful uses of outer space, so placing SAC in charge of a major air force space program seemed politically unwise. Knowing the many possible applications for a satellite system, Ritland did not want the air force to "confuse space operations with space warfare." While a combat command may use a satellite either directly or otherwise just as they use aircraft, other military and nonmilitary users of space have "a much wider and more enduringly constructive interest in space." To avoid restricting future decisions, the initial organization and operational concept for WS-117L, Ritland suggested, should begin as a system operated by the military as a service to others as well as itself.[59] Operation by the military made sense in that only the military had the resources, organization, and experience necessary to support such a program in the late 1950s.

To make the point well known that the Air Force Ballistic Missile Division provided space research and development services for the United States, the agency publicized its undertakings. Given the go-ahead for a satellite program, in 1958 the air force prepared an initial press release for the DISCOVERER series of test launches, masking the true CORONA reconnaissance satellite with the biomedical research cover story. The press release described the new satellite as important for developing systems and techniques that would be employed in the production and operation of space vehicles, thus introducing the fallacy that WS-117L was simply a test program, not a program with

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[59] Col. O. J. Ritland, Draft of "Preliminary Operational Concept of 117L," 6.

operational goals. The air force public affairs specialists included in the release a series of questions, which they answered themselves, as significant for what they did not say as for what they did say. Of particular interest are the bald-faced lies.

Question:	Is the Discoverer a reconnaissance satellite?
Answer:	No.
Question:	Is it part of the Weapon System 117L--or Sentry--or Pied Piper program?
Answer:	No....
Question:	If the Discoverer is not part of WS117L, and if it is not a reconnaissance satellite, will it make a contribution to a reconnaissance satellite program?
Answer:	Ultimately, the Discoverer, like any satellite that achieves orbital capacity, can be expected to make a contribution to *every* other satellite program. However, reconnaissance as such is still very much in the research stage and must, of necessity, be considered in terms of future development....
Question:	Why is Discoverer being placed in a polar orbit?
Answer:	Polar orbit is the only one from Vandenberg AFB with hardware presently available. Eastward launch from Vandenberg is prevented by safety considerations. Launch to the West would entail an unacceptable speed penalty.
Question:	Why is a low altitude orbit being used?
Answer:	High altitudes are not possible with the weight-thrust rationale [sic] established for Discoverer. Because of testing instrument requirements, a rather heavy payload is contemplated.
Question:	Why not launch the Discoverer from Cape Canaveral?
Answer:	The facilities at Cape Canaveral are overloaded. One of the purposes in constructing a missile range on the West Coast was to reduce the burden on the Atlantic Range.[60]

In addition, as this press release illustrates, to those seeking to wrest satellite command and control from its inventors, the issue of secrecy dominated. The air force believed in the logic behind itself as the organization to control CORONA and its associated command and control network.

Any further air force attempts at publicity died in June 1959. ARPA Director Johnson ordered cancellation of the E-5 (photographic recovery) portion of SENTRY, the

[60] "Proposed Initial Press Release," 6 Nov. 1958, NRO, 2/A/0078.

official name for the reconnaissance mission of WS-117L, because "it duplicated, rather than complemented other planned programs," although he did not mention which specific ones.[61] Johnson officially and publicly cancelled the reconnaissance satellite, but the essential elements like satellite command and control remained because the cover story for CORONA, the DISCOVERER biomedical research program, had already been well-established.

The air force underscored its position in discussions over the location of the central intelligence-processing center--not in the Washington area, but in the Omaha area. In its early development plans, the AFBMD and Lockheed assigned responsibility for the Advanced Reconnaissance System Intelligence Center (ARSIC) to Eastman Kodak, producers of the film for CORONA's camera, and the government, providers of the facilities. AFBMD primarily saw ARSIC as solving the problem of data handling on such a large-scale that machine and personnel demands exceeded realistic values. In the April 1956 development plan, Lockheed wanted the ARSIC to be "managed and operated by contractor personnel to provide a stable organizational structure with full exploitation of accumulated experience."[62] Lockheed attempted to use the ARSIC to minimize redundancy and speed up interpretation of reconnaissance data. Not everyone thought the location of the ARSIC near SAC headquarters was such a good idea. The intelligence

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[61] MSG, Secretary of the Air Force Douglas to General Schriever, no subj., 6 June 1959, AFHRA, K243.012-36; MEMO, Roy Johnson, Director, ARPA, to Secretary of the Air Force Douglas, SUBJ: "Reconnaissance Satellites and Manned Space Exploration," 23 Feb. 1958, AFHRA, K243.012-36.

[62] *WS-117L Advanced Reconnaissance System Development Plan*, 1 Nov. 1956, Volume II *Subsystem Plans, J. Ground Support and Training*, 12, AFHRA, K243.8636-37.

community remained reluctant to grant access to their work, requirements, methods, and organization to nonoperating intelligence people.[63]

Development plans included putting the ARSIC at Offutt AFB, Nebraska, because the air force wanted to assign SAC, the presumed user of the photos to be gathered, as the operating command for WS-117L. The air force chose SAC as WS-117L's operator for two reasons: to get the system away from Washington, thus preventing the navy from expanding its role in military space operations, and because they expected the overall satellite tracking mission to evolve eventually into including an antisatellite mission ("tracking" at this time meant command and control as well as detecting and tracking so-called "silent satellites," which referred to friendly but inoperative satellites and all enemy satellites).[64] The air force also planned to collocate the Central Tracking and Data Acquisition Station in Nebraska, and to staff it with military personnel as soon as possible.[65]

General Thomas Power, Commander-in-Chief of the Strategic Air Command, believing in the "urgent need" for information generated by the missile threat from the USSR, saw any slipping of the schedule as "inconceivable" and wanted the Air Staff to provide money required to get the satellite operational by July 1962 and the MIDAS

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[63] Report, Major Weinberg, SUBJ: Intelligence Data Handling System Support for WS-117L," 20 Feb. 1957, AFHRA, K243.012-36.

[64] MEMO, Maj. Gen. C. M. McCorkle, Asst. Chief of Staff of the Air Force for Guided Missiles, SUBJ: "Conflicting Interests in Astronautics Projects," to Secretary of the Air Force Douglas, 30 June 1958, AFHRA, K243.012-36.

[65] MEMO, Col. C. H. Terhune, Deputy Commander for Weapon Systems, SUBJ: "Status of ARSIC Planning," to Gen. O. J. Ritland, Vice Commander, Western Development Division, 26 Feb. 1958, AFHRA, K243.012-36.

infrared missile warning satellite by July 1963, "even at the expense of other programs." Power's proposal included restricting facilities construction and equipment to the minimum essential for the SAMOS and MIDAS programs only because he thought it "absolutely essential" to get the SAMOS and MIDAS programs "off of dead center."[66] He wanted as soon as possible a "basic, operationally useable system. The sophistication and any required increased scope of activities should come later."[67] Power had a goal of as much information as possible as soon as possible.

Air Force Chief of Staff General Thomas D. White also believed it essential that the air force operate WS-117L, but understood that SAC would not be the only user of the intelligence data gathered. General White responded to General Power asking for patience because of problems "other than operational" in the WS-117L program, making it "abundantly clear" that the air force would not be allowed to implement the operations concept which had SAC as the main operator. In particular, General White cancelled SAC's plan to have the ARSIC at the old Martin bomber plant near Omaha. "Operate" in General White's mind meant "launch, injection, command and control on orbit, data retrieval, data reduction as required, and dissemination of this new data to designated users" but did not include data exploitation to satisfy air force needs. "Other agencies," White told Power, would accomplish data exploitation. The air force could operate WS-

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[66] MSG, Gen. Power, CINCSAC, no subj., to Gen. Schriever and Gen. Ritland, 30 Dec. 1959, AFHRA, K243.012-36.

[67] LTR, Gen. Power, no subj., to Gen. White, Chief of Staff, 16 June 1960, AFHRA, K243.012-36.

117L as "a national asset responsive to all participating agencies."[68] The new managers began to assert themselves, but they still had to be aware of the real drivers behind satellite-based reconnaissance and command and control, the CIA and the NRO.

Some outside the air force, aware of the relationship of the reconnaissance satellite program with agencies outside the air force, participated in the debate over just who should manage the satellite command and control system. In an interoffice memo, Dr. Reuben F. Mettler of Space Technology Laboratories, a division of Ramo-Wooldridge, the prime systems engineering and technical direction contractor on WS-117L, tried to show how the transition from developmental to operational status in satellites would be different from ballistic missiles. Mettler believed the division of responsibility between the developing agency (the Air Force Ballistic Missile Division) and the operating agency (Strategic Air Command) required new ways of thinking. First, Mettler knew that WS-117L might actually produce operational information from the first launch, well before the system had sufficiently matured to put the conventional "operational" label on WS-117L, let alone turn it over to SAC's checklist-driven operators. Second, Mettler expected that continued developmental improvement of various components or subsystems would prevent a stable configuration of the satellite system. He suggested a more conservative approach to the satellite system, turning over satellites to SAC one-by-one after AFBMD had performed certain prescribed tests once a vehicle had reached orbit. If it passed the tests, the vehicle could be turned over to by-the-book SAC, who would then command the satellite on and off as required and operate

[68] MEMO, Gen. White, no subj., to Gen. Power, 29 June 1960, AFHRA, K243.012-36.

the readout stations; if the satellite failed the tests, AFBMD could continue to use the vehicle for special developmental purposes.[69] In his own way, Mettler suggested that AFBMD delay as long as possible the turnover of the command and control system to the operational air force.

In a reply to Mettler, General Ritland, now Commander of the Air Force Ballistic Missile Division, acknowledged the one-by-one turnover of satellites, but considered it unnecessary. Ritland assured Mettler that AFBMD had established ground rules with SAC and Air Defense Command, who would operate the missile launch warning satellites of the MIDAS program, concerning the accomplishment of certain specified research and development objectives. In essence, before making the WS-117L program operational, the basic configurations, facilities, and procedures had to be well established and proven or AFBMD would not turn over the programs under their control to an operational command.[70] This method is how the air force had always turned over new weapon systems to operational commands; clearly, not everyone thought it such a good idea in the particular case of the WS-117L satellite program.

Dr. Herbert York, Assistant Secretary of the Air Force for Research and Development, agreed with Mettler. York believed in the necessity of thoroughly testing all elements of the system in order to evaluate a particular method of reconnaissance. In fact, he asked the Secretary of Defense to stop the expenditure of funds for personnel

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[69] MEMO, R. F. Mettler, "SUBJ: Operating Concepts for Military Satellite Systems," to Gen. Ritland, 2 Nov. 1959, AFHRA, K243.012-36.

[70] MEMO, Maj. Gen. O. J. Ritland, SUBJ: Operational Concept for Military Satellite Systems, to Dr. Mettler, 4 Dec. 1959, AFHRA, K243.012-36.

training, acquisition of land for new facilities, including refurbishing the Martin plant in Omaha, and data links from Vandenberg to Sunnyvale. In fact, York recommended to new Secretary of the Air Force Dudley C. Sharp that he cut back the budget for the reconnaissance satellite program to fund only one tracking and acquisition station.[71] York's deliberate approach tried to keep the inventors of the system from fading too far away from the center of the satellite action.

Air Force Vice Chief of Staff Gen. Curtis LeMay settled the debate temporarily. In a 5 August 1959 letter to ARDC and SAC, the former SAC Commander-in-Chief assigned his old command the responsibility of operational planning for employment and control of the Advanced Reconnaissance System, but classified that knowledge secret. And because the air force expected WS-117L to have operational potential right away, LeMay wanted SAC responsible for any data obtained from space and for providing information and data necessary to help in its continued development.[72] LeMay did not assign a specific timetable to the turnover of the WS-117L program to SAC from ARDC.

To keep the eventual plans secret, the air force advertised the Air Research and Development Command as the WS-117L developer and operator and indicated that ARDC would activate the system and make it operational. The air force gave Air Defense Command operational control over MIDAS, the space-based infrared missile launch detection system. The air force did not release its actual goal to staff the

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[71] MEMO, Herbert York, Asst. Secretary of the Air Force for R&D, SUBJ: Intelligence System SAMOS, to Secretary of the Air Force Dudley C. Sharp, 7 Dec. 1959, AFHRA, K243.012-36.

[72] MEMO, Gen. Curtis LeMay, Air Force Vice Chief of Staff, SUBJ: "Assignment of Operational Planning Responsibility," to Commander, ARDC, and Commander-in-Chief, SAC, 5 Aug. 1959, AFHRA, K243.012-36.

reconnaissance system with Strategic Air Command and ARDC personnel, or the intention to transfer the entire system to SAC eventually, including the Air Force Satellite Control Facility and almost all of its subordinate units, which the air force classified top secret and placed on a strict need-to-know basis.[73]

Publicly, to develop and operate the new system, the air force created a new service organization in April 1959 to "support military space development and operational employment" of military satellites. Air Research and Development Command organized the 6594th Test Wing (Satellite) under the leadership of Lt. Col. Charles A. ("Moose") Mathison to "Execute development, test, and evaluation programs in support of the DISCOVERER, SAMOS and MIDAS programs" in order to develop and achieve "the initial USAF military capability to operate and maintain" them. The 6594th Test Wing (Satellite) set as its number-one goal achieving the capability to "operate and maintain the SAMOS and MIDAS systems *with assigned military personnel* to include launching, tracking, data acquisition, data processing, data reduction and recovery for orbital space vehicles in accordance with the approved operational program schedules."[74] The new management had now taken its place.

In the April 1960 edition of *Air Force/Space Digest*, Brig. Gen. Charles H. Terhune, Jr., new vice commander of the Air Force Ballistic Missile Division, talked

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[73] MSG, SecAF to Gen. Schriever, no subj., 5 Feb. 1959; MSG, Gen. Schriever, no subj., to Col. Curtin, AFBMD, 1 Oct. 1958, AFHRA. The 6593d Test Squadron (Special), which caught returning satellites, would be transferred to the Air Rescue Service, and the Vandenberg Tracking Station would remain in ARDC for follow-on R&D.

[74] Gen. Ritland, "Mission Statement for 6594th Test Wing," 26 Oct. 1959, AFHRA, K243.012-36. Emphasis added.

about "the last great frontier." He described the Sunnyvale-based 6594th Test Wing (Satellite) as "the nation's first organization set up exclusively to satisfy the launch, tracking, acquisition, and recovery requirements of a satellite program." An AFBMD news release issued in October 1960 said nothing about Strategic Air Command or, in fact, Air Defense Command. The news release described Project SAMOS simply as "a research and development program to determine the capabilities for making observations of the earth from satellites." It also made clear that the Vandenberg, Hawaii, and Kodiak tracking stations had primary responsibility for on-orbit telemetry, tracking, and commanding, while the Satellite Test Center received all orbital data and exercised command and control over SAMOS.[75]

Also in the April 1960 edition of *Air Force/Space Digest*, General Terhune described the blue-suit operations in Sunnyvale. The goal of operations now included direction to achieve "at the earliest practical time" the capability to operate and maintain with military personnel, the command, control, engineering data processing and computing facilities associated with the Satellite Test Annex in Sunnyvale and the tracking stations in Alaska, California, Hawaii, and New Hampshire.[76] Tracking, control and communication with orbiting vehicles would be performed by staffs of NCOs whom the air force considered similar to the troops servicing fighters, bombers, and cargo planes. Civilian technicians would do research and development, "but with operational

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[75] Charles H. Terhune, Jr., "In the '*Soaring Sixties*' Man is on His Way--Up," *Air Force/Space Digest* (April 1960): 71; "SAMOS I Fact Sheet," 11 October 1960, AFHRA, K243.012-36.

[76] Gen. Ritland, "Mission Statement for 6594th Test Wing," 29 Dec 1960, AFHRA, K243.012-36.

systems, these jobs will belong to the men...[sic] and women...[sic] who wear Air Force blue."[77]

Even at this early stage, using uniformed personnel to perform all operations and maintenance tasks proved problematic. The Standardization Division of the 6594th Test Wing (Satellite) undertook a study of the feasibility of Air Force maintenance of the Programmable Integrated Computer System (PICE), a large magnetic core buffer using the Control Data Corporation CDC 1604 computer and meant to store data from external sources to make it available upon request, what we would today call memory. The standardization office found that it reasonable to proceed with a training course for air force personnel who would ultimately assume maintenance responsibility for the PICE system. PICE's condition, still in "engineering status," meant that contractors had not delivered certain peripheral equipment or handbooks, nor had they established any official procedures, making it doubtful that the air force could assume full maintenance capability before January 1962.[78] The system inventors demonstrated their reluctance to give way to the new management.

Sole responsibility for operating the tracking station under contract to ARDC belonged to Lockheed. In Hawaii, at the 6593rd Instrumentation Squadron, the air force assigned military personnel during the second half of 1960 for duty with the civilian

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[77] Terhune, "In the '*Soaring Sixties*,'" 71.

[78] *History of the 6594 Test Wing (Satellite)*, 1 July-31 Dec. 1960, 1, 15, AFSPC/HO, Box 3-3-1; 6594 Aerospace Test Wing, *Satellite Control Facilities Capabilities Manual*, appended to *History of the 6594 Test Wing (Satellite)*, 1 July-31 Dec. 1960. According to Ed McMahon, in an electronic mail to the author, PICE was originally called the Lockheed Integrated Control Equipment until someone high up realized what that name made the acronym.

contractor “in training and recovering orbiting vehicles.” The station’s contractor personnel integrated enlisted air force technicians as crew members into the subsystems that comprised the tracking station, including the antennas, data readout, and communications networks. Air force personnel willingly assumed whatever positions Lockheed allocated them. According to one partial observer, from the beginning Lockheed personnel accepted air force personnel but hesitated over concerns about job security. Much to their relief, air force participation showed the Lockheed personnel their ability to work with the contractors, not to replace the Lockheed workers. Air force personnel came under the direct supervision of Lockheed managers and rapidly moved around the station to supplement their operational knowledge, capability, and effectiveness.[79]

At the Satellite Test Center in Sunnyvale, earlier corners cut for Lockheed in the area of documentation began to hurt the air force in the transition to blue suit operations, preventing the new management from taking over as smoothly as they wanted. Air force personnel, when they took over responsibility for Flight Test Operations in Data Processing, had a lot of trouble finding written work explaining the specifics of accomplishing the mission. After discussing the matter with Lockheed personnel assigned to the section, the airmen found out that very little existed in writing concerning the operation, and there were absolutely no job procedures. They partially solved the problem by sitting down with their Lockheed counterparts and thoroughly reviewing every procedure. The information enabled the air force to write job procedures, develop

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[79] *History of the 6594 Test Wing (Satellite)*, 1 July-31 Dec. 1960, Appendix 5, 2.

task checklists, and prepare an interim manual on computer procedures for flight operations.[80] The contractors remained a part of the operation to help with procedures because the air force believed they did not have enough information to operate the system alone.

When Secretary of Defense McNamara assigned the air force responsibility for research, development, test, and evaluation of space programs and projects on 6 March 1961, the service took a further step closer to management of military space operations. DoD Directive 5160.32 effectively made the air force the DoD executive agent for all space development programs, regardless of which service ultimately used it. The directive essentially reversed the decision to assign responsibility of space systems development to the using agency, which Neil McElroy, McNamara's predecessor, had issued in September 1959.[81] The air force now had to direct all field test operations actively, including operations in Sunnyvale, a step beyond just supervising the contractor's work.

On 1 April 1961, the air force stepped to the front of the military's space program and Lockheed stepped back when the service took over responsibility for operations and maintenance of all ground-space equipment at the tracking stations from Lockheed and its subcontractors. The air force ordered the 6594th Aerospace Test Wing (Satellite) to develop "the capability to operate and support, with military personnel, selected elements

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[80] *History of the 6594 Test Wing (Satellite)*, 1 Jan.-30 June 1961, 31, AFSPC/HO, Box 3-3-1.

[81] Robert S. McNamara, "Department of Defense Directive 5160.32," March 6, 1961, in Richard I. Wolf, *The United States Air Force Basic Documents on Roles and Missions* (Washington: Office of Air Force History, 1987), 363-4; Futrell, *Ideas, Concepts and Doctrine*, vol. 1, 292-95, 386-87. The policy was reversed again in 1970.

of satellite systems." But the directive left an out: "Where contractor operation or support is more economical and effective, it will be used." Therefore, Air Research and Development Command assigned responsibility for operation of the satellite control facilities and direct supervision on all technical and logistic support to the 6594th Aerospace Test Wing (Satellite). This change in responsibility represented a major shift in air force policy because to this point, Lockheed had been the operator and the 6594th only monitored Lockheed's operations.[82] Now the military managers of the Air Force Satellite Control Facility stepped up to take charge from the experienced contractors.

The air force now played a more direct role in the operations and maintenance of the stations, although the personnel remained mostly the same. The AFSCF prepared and published operations and equipment integration procedures, long-range planning information, and directed how to brief crew personnel on mission requirements. At New Boston, the squadron operations officer, an air force lieutenant colonel and the number-two officer on the station, introduced a three-crew rotation with an air force officer in command of each crew. This arrangement permitted 24-hour staffing of the tracking station under constant and direct air force control. A satellite operations crew of 62 military and contractor personnel, almost evenly split between the two groups, conducted operations.[83]

Management's new ways caused a few ripples for contractors who did not move every two or three years and earned a decent wage for the most part. Contractors now

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[82] *Satellite Control Facilities Capabilities Manual*, B-1.

[83] *History of the 6594 Test Wing (Satellite)*, 1 July-31 Dec. 1961, Appendix 7, 3, AFSPC/HO, Box 3-3-1.

backed up airmen on console, assisting where necessary. For example, a staff sergeant usually staffed one operating position called the "seventeen-inch scope readout." During a normal satellite support, the sergeant read off the scope the binary telemetry from the satellite, confirming that a command went out to the satellite and that the satellite properly acknowledged it. The readout may also have indicated that further commanding might be required, so the sergeant's report had to be accurate and timely. One sergeant took a particularly long time and frequently provided the wrong information, forcing the assistant shift supervisor, a contractor, to back him up from across the room while also running the tape recorders. The contractors strove for one hundred percent error-free supports, and came close most of the time. The air force eventually made the basis for the contract award fee the number of errors.[84]

Operations went just as smoothly after the change as before. On 18 August 1960, DISCOVERER XIV went into orbit as planned from its launch pad at Vandenberg AFB at 1215 Pacific Time. The seventeen-hundred-pound satellite with its three-hundred-pound reentry capsule[85] circled the earth every 94.5 minutes at 17,568 miles per hour with a perigee of 116 miles and an apogee of 502 miles. At the windowless Satellite Test Center, Col. Alvin N. Moore, commander of the 6594th Test Wing (Satellite), along with

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[84] Howard Althouse, electronic mail to author, SUBJ: "BOSS," 29 Nov 2000.

[85] Sputnik I (4 Oct. 1957) weighed almost 184 pounds and orbited at a maximum altitude of 586 miles. Sputnik II (3 Nov. 1957), carrying the dog Laika, weighed over eleven hundred pounds and reached an altitude of over eleven hundred miles. Sputnik III (15 May 1958) weighed over three thousand pounds and orbited at up to one thousand miles. The American satellites Explorer I (31 Jan. 1958) and Vanguard I (17 March 1958) weighed thirty pounds and 3.5 pounds, respectively. They orbited at maximum altitudes of over 1,412 miles and 1,679 miles, respectively. (Source: J. K. Davies, *Space Exploration* [Edinburgh, UK: Chambers, 1992], 221-22.)

high-ranking air force officers and Lockheed engineers, kept a close vigil on the vehicle. Information from the tracking stations at Vandenberg, Alaska, New Hampshire, Hawaii, and at sea from the USNS *Private Joe E. Mann*, poured into the Satellite Test Center by voice and teletype. Although supporting the contractor, Colonel Moore's unit developed a real air force capability to operate any and all satellite systems whenever they become operational.[86]

The discerning face of the new Aerospace Force could be found in the Air Force Ballistic Missile Division. Curious young scientists and engineers, both civilians and military, built the new organization and instilled an ambitious focus. The leadership, a mix of seasoned officers, noncommissioned officers, and contractors, knew that experience gained through failure could be just as important as success.[87] Young technicians with stripes on their arms stood behind them with new knowledge and new tools, tuning and adjusting the systems. The system tolerated failures in those days; it does not tolerate failure today. National leaders, the press, the public, and so on, placed a different premium on success because no one had ever launched satellites into space and used them to gather intelligence. Today we talk about learning from failure; these inventor-entrepreneurs formalized that process in the early days, even if they did not call it "lessons learned." Said one former operator: "We just called it experience. But that's one thing we were doing, trying to go to school on each day, on each thing we did, on those things that would work, on those things that worked well, and on those things that

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[86] Blair, "From Saddles to Satellites," 9; Clifford, "Discoverer--Trailblazer to Space," 12-19.

[87] Blair, "From Saddles to Satellites," 13.

didn't work so well."[88] As another veteran summarized the process, "Let's have a Coke, say hello to the wife and kids, then start over again."[89]

Manager-entrepreneurs, both contractors and military officers, began to replace the inventors of satellite command and control, who faded from the center of air force research and development activity. Some in the air force believed that the sole user of the WS-117L photos should be SAC, the nation's foremost nuclear command. What they did not understand, or did not want to, was that other agencies in the American government, particularly the CIA, also considered it necessary to have WS-117L's data. And those people not privy to the decision-makers at the highest levels often assumed that the air force should be the sole operator of the WS-117L system. The air force did successfully argue that a service organization should be responsible for command and control of the WS-117L program, creating the 6594th Test Wing (Satellite) to perform that service function and thus keeping the majority of space operations in the air force, even if the data did make its way elsewhere. The 6594th displaced the inventors of satellite command and control with new management, bringing the Air Force Satellite Control Facility new opportunities.

Summary

The innovation phase in the technological system's development illustrates how the large technological system of military satellite command and control came into use.

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[88] McCartney interview by author.

[89] Captain Rob Roy, in Blair, "From Saddles to Satellites," 17.

Most inside and outside the air force saw satellite-based reconnaissance as a radical concept, but no one saw satellite command and control as anything but a conservative idea because it used older practices borrowed from the ICBM test environment. In their attempt to create a satellite command and control system out of tried and true techniques, those presiding over Subsystem H, the Air Force Ballistic Missile Division, and Lockheed, tried to develop satellite command and control as much as possible. At the urging of the contractors and the air force, the size of the system began to expand, thus further illustrating the social construction of satellite command and control technology. In addition, numerous players, each attempting to add an ounce of their own control to the system, stood in the way of Lockheed and the air force truly controlling the new satellite command and control system. By 1961, the manager-entrepreneurs, both contractors and military officers, had begun to replace the inventors of satellite command and control, who moved from this important point of air force space activity to other satellite programs and other challenges.

Further, after successfully arguing that a service organization should be responsible for command and control of the WS-117L program, not a combatant command, the air force created a more complex system consisting of service facilities. The creation of the 6594th Test Wing (Satellite) to service satellites thus created the belief that satellite command and control was a critical air force function. The 6594th began the displacement of the inventors of satellite command and control with new management that had to face new challenges in the mid-1960s, including how to deal with the growth of the Air Force Satellite Control Facility. The air force had certainly managed to "get off dead center," but as yet the new innovation still had only one

customer, the CIA's CORONA reconnaissance satellite. As engineers moved the AFSCF out of the innovation phase, developed the technology, and refined their techniques of satellite command and control, Air Force Satellite Control Facility engineers found they faced new challenges.

CHAPTER 4

"TOO MANY FINGERS IN THE PIE":

GROWING INTO A SATELLITE CONTROL SYSTEM

> [There] was a different premium on success but, hey, folks were kind of stumbling around. They'd never done this [space operations] before. As my daddy would say, "This time and once more will make twice we did that."[1]
>
> -- Lt. Gen. Forrest McCartney, USAF, Retired
> Operator of CORONA Flight 14, which took the first photographs of the USSR recovered from space

> [W]e were trying to get the show on the road and get a mission for ourselves.[2]
>
> -- General Howell M. Estes, Jr., USAF, Retired
> Former Vice Commander, Air Force Systems Command

On DISCOVERER XIV's seventeenth orbit, a controller at the Kodiak remote tracking station transmitted the eject command to the spacecraft. Three hundred miles above the earth, explosive bolts fired and separated the film-carrying reentry vehicle from the Agena vehicle, beginning the gold-plated bucket's fiery journey back to earth. At fifty thousand feet, the capsule's parachute opened and it began transmitting its automatic radio beacon. As the capsule's descent slowed to sixteen hundred feet per second, air

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[1] McCartney interview by author. General McCartney, a 1952 Alabama Polytechnic Institute graduate, served as one of the first three Air Force captains who controlled CORONA vehicles, though without knowing its true mission, at first. The CIA and the Air Force eventually cleared him and his compatriots for the entire CORONA program. In fall 2001, the Air Force inducted him into the Space and Missile Pioneers Hall of Fame.

[2] Howell M. Estes, Jr., General, Retired, interview with Lt. Col. Robert G. Zimmerman and Lt. Col. Lyn R. Officer, Oakland, Calif., 27-30 Aug. 1973, transcript, 253, AFHRA, K239.0512-1413. General Estes went on to command Military Airlift Command; his son, Howell M. Estes, III, later commanded Air Force Space Command.

force Capt. Harold Mitchell and the crew of *Pelican Nine*, a recovery-equipped C-119 Flying Boxcar, caught up to the descending capsule in plenty of time. Mitchell completed two passes over the parachute, each one closer to the water than the one before, unable to snag the reentry vehicle. On the third pass, a slight tug on the C-119's controls told Mitchell he would go down in air force history as the first pilot "to catch a falling star."[3]

By the time this highly significant event in aerospace history took place, the Air Force Satellite Control Facility supported three military satellite programs: DISCOVERER, the cover story for the CORONA imaging satellite; MIDAS, America's first infrared missile warning satellite; and SAMOS, the ancestor of all modern reconnaissance satellites. Each satellite program used a different combination of remote tracking stations with some significantly different tracking station equipment, personnel, quality of performance, and various methods of operation.[4] Engineers had not yet developed digital space computers, requiring some technical creativity with existing equipment. Tracking, orbit determination, telemetry and data analysis, and command processing and generation all required extensive data processing using relatively simple and extremely bulky analog computers. In the early approach to satellite command and control, each tracking station individually analyzed, interpreted, and reduced most of a

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[3] John Nammack, "C-119's Third Pass Snares Discoverer," *Space Technology* 3 (Oct. 1960): 44-45; Clifford, "Discoverer--Trailblazer to Space," 16-19; Robert A. Flavell, "To Catch a Falling Star: Aerial Recovery of Space Objects," *Air Power History* 43 (fall 1994): 24-26.

[4] Don Stevenson, untitled history of the AFSCF (Sunnyvale, CA: Aerospace Corporation, n.d.). Provided by Mr. Stevenson to the author.

satellite's data. Controllers in Sunnyvale handled the operation of the payload, the general vehicle status and control of the satellite.

To perform the orbital calculations, the Air Force Satellite Control Facility used several general-purpose computers, including two large Control Data Corporation CDC 1604 computers. The CDC 1604, a fully transistorized, stored-program, general-purpose computer, had 32,768 forty-eight-bit words of core memory storage. Vandenberg and New Hampshire also each had a single CDC 1604 computer to perform data analysis and control, making them essentially stand-alone command and control stations.[5] These rudimentary ground sites had simple antennas to track the satellite beacon, modified World War II-era SCR-584 radars for transmitting commands and receiving telemetry, and telemetry receivers and transmitters to reset the satellite "programming" when needed. Telephone and teletype circuits connected the ground sites to the Satellite Test Center in Sunnyvale.

Adequate communications made--and make--orbiting satellites possible. One of the most extensive computer systems in the world fed the control room in the Satellite Test Center at Sunnyvale, one of the world's most modern communications hubs. The test controller--the operator giving commands to the satellite--and the test director--the program office expert on all on-board systems--had closed-circuit television screens, push-button communications panels, and two-way headsets all feeding them information. Other consoles recorded the communications. Twenty-six television cameras showed the

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[5] 1st Lt. Joseph H. Binsack, "Satellite Control Facility Capabilities," in *Proceedings of the IAS National Tracking and Command of Aerospace Vehicles Symposium*, February 19-21, 1962 (New York: Institute of Aerospace Sciences, 1962), 135-7.

satellite and reentry capsule plotting boards. Incoming and outgoing messages on the teletype systems and any combination of voice conferences kept the test crews informed and up-to-date. Viewgraph screens showed current weather conditions over the recovery site, maps, plots, and anything else the crew needed to know. Time ticked off on three separate systems in local time (Pacific), Zulu Time (Greenwich Mean Time), and system time (in seconds).[6] If anything, the operators had too much information.

This large technological system evolved in the early 1960s into a true satellite command and control network only by overcoming a variety of challenges. As the system grew, problems developed as components in the system fell behind or out of phase with the others. One major problem involved communications between the remote tracking stations and the Satellite Test Center. In order to handle a vehicle's requirements, the command center's network connected specific equipment, subsystems, and the remote tracking stations. At first, an antenna connected to a specific receiver interfaced with its own program-peculiar control, display and command equipment, but the technology could not process the data as rapidly as system engineers desired. The equipment at the remote tracking stations required hours or even days to configure and check out for each of the satellite programs on which the air force "experimented."

By the early 1960s, the air force satellite command and control system had evolved from a simple system designed to support one satellite program, CORONA, into an increasingly cumbersome hodgepodge of equipment and procedures. By the early 1960s, the AFSCF began running into new challenges. Long satellite life exposed a

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[6] Blair, "From Saddles to Satellites," 16.

number of problems that operation of the system had not previously uncovered. For example, the early timing system simply counted the seconds after liftoff. Because early CORONA flights only lasted a maximum of seventeen orbits, programmers limited the timing system capacity to about forty-eight hours, or 172,800 mission-elapsed seconds. With more than one vehicle on orbit at the same time, engineers scrapped the system of counting mission-elapsed seconds in favor of using Greenwich Mean Time. With one of the early vehicles on orbit over New Year's a new problem arose: programming in the ephemeris computer could not handle the year change and it refused to provide tracking predictions. Controllers established a temporary solution by giving the computer some fictitious launch data and it started to generate the orbital data all over again.[7] Even then, on-orbit operations only lasted a matter of a few days.

In sum, lack of engineering foresight did not cause every problem. In this complex technological system, its environment sometimes also presented new challenges to be overcome, such as what to do about new satellite programs on orbit. Furthermore, when experts could not correct a major problem within the context of the existing system, the solution brought about a new and competing system. The problem of the weather satellites became a radical system as the AFSCF became a conservative one.[8] The AFSCF was not meant to turn out the way it did and in looking at the competing weather satellite program, one can see that the AFSCF could have turned out quite differently.

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[7] Keith R. Smith, electronic mail to author, SUBJ: "Your Letter," 16 Nov. 2000.

[8] Hughes, "Evolution of Large Systems," 73-75.

Like every large technological system, military or civilian, the Air Force Satellite Control Facility evolved because of the interaction of human beings with technology.

The inventors of the Air Force Satellite Control Facility had created the idea of a satellite command and control system more than a real satellite command and control network. This chapter will show that by overcoming technical and operational challenges, engineers created a satellite command and control network capable of supporting multiple reconnaissance satellites.

Technological Challenges

The earliest configuration of the Kodiak Tracking Station is a good example of the basic design of the first satellite command and control system. Two antennas, a VERLORT (Very Long Range Tracking) three-pulse tracking and commanding radar (an old bomb scoring radar system modified to accommodate satellite orbital distances) and a tri-helix telemetry-receiving antenna served the station. The station communicated offsite by teletype or telephone. Encrypted teletype messages told Kodiak controllers the launch and satellite support operation schedules, and then after each satellite support operation, they sent the logs and telemetry readouts back by teletype, telephone, or in the mail. Controllers used real-time voice, transmitting in the clear, for every other operation.[9]

The simple design meant that technicians could easily overcome some problems. In late 1961, a taper-pin fell out of the elevation mechanism of the tri-helix antenna early

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[9] Marv Sumner, electronic mail to author, SUBJ: "AFSCN History,"15 Dec. 1999.

during a satellite support operation at Kodiak. When the pin fell out, the elevation axis fell to near zero and the drive motor could not raise the antenna. The azimuth axis continued to operate properly and the sloppy beam pattern of the tri-helix antenna coupled with the powerful transmitter meant that the satellite support continued normally, collecting all the data even though the antenna most likely never pointed directly at the satellite. The antenna motion followed along the horizon while the satellite passed nearly overhead.[10] The satellite transmitter had more power than needed and the ground antenna had a higher gain than needed, demonstrating just how much the satellite command and control community still had to refine.

The lack of experience in satellite command and control also meant the tracking stations spent three or four weeks of operations rehearsals getting up to a maximum effort for a launch. The transmitter oscillators required thirty minutes to tune, necessitating a long time between satellite support operations and part of the reason for a lack of speed in satellite operations. In addition, controllers had to tune the bore sight transmitter and tunable bandpass filter, meaning that they took about forty-five minutes to change operating frequencies. Extremely maintenance- and personnel-intensive, the underdeveloped satellite command and control system nevertheless worked from the first launch, even if the boosters and satellites did not.

Information flow and data processing remained one of the most convoluted aspects in the Air Force Satellite Control Facility in the late 1950s. The data flow to get a command plan to a tracking station required a separate twenty-four step procedure for

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[10] Marv Sumner, electronic mail to author, SUBJ: "AFSCN History," 5 Jan. 2000.

each site. The procedure for transmitting an Acquisition Programmer Tape to a remote tracking station began with verbal arrangements to verify readiness to transmit and receive by teletype. Transmission had to be at acquisition of satellite signal minus thirty-five minutes in order to allow a preplot of the tape, verification of its validity, and to make necessary adjustments to the equipment. Stations using computers linked through the programmable integrated communications equipment (PICE) experienced a shorter transmission time, but there had to be enough time to validate the program, print out the data, and distribute them to specified users.[11]

To make matters worse, the Air Force Satellite Control Facility also had two basic satellite tracking systems. First, the VERLORT radar system used frequencies in the S-band, normally operating in conjunction with an active beacon on the satellite to supply range and angle determination to determine ephemeredes (orbital parameters). Second, the newer tracking system used the Doppler frequency shift of an active satellite as it moved closer to or farther from the receiver. The basic system employed a transponder on the satellite, which returned radio waves the ground station sent to the vehicle. Ground station computers compared the transmitted and received frequencies to derive the Doppler information. The vehicle transmitted its health and status through a telemetry link to the ground station where controllers analyzed the data or sent the information to the satellite controllers in Sunnyvale. One telemetry system employed frequency division multiplexing, producing eighteen channels of data in the VHF radio band, with some information multiplexed onto certain channels. The other telemetry

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[11] Philco Corp., *Multiple Satellite Control Facility Study*, 5 Jan. 1962, DTIC, AD452208.

system used time division multiplexing, a general purpose and much more flexible system, but ultimately slower and carrying less data than frequency division multiplexing. To control the vehicle in real-time, rather than using commands stored on the vehicle exclusively, controllers in Sunnyvale used two basic commanding systems. One used digital modulation of VERLORT radar pulses while the other used analog modulation of radar transmission, a much slower method.[12]

The technological constraints on the Air Force Satellite Control Facility affected the ability of operators to carry out tasks in "real-time." One of the most important constraints was the significance of an operator's decision. The time required to receive and analyze data, make decisions, and generate commands could be less than five minutes for a satellite with a three-hundred-nautical-mile orbit. Once an operator made a decision, it became nearly impossible to take corrective action, given the short satellite support operation times at the stations because of low orbits. Controllers "planned the flight, and flew the plan." For near-earth orbits, controllers used the "Six Second Rule: Two seconds to identify the problem, two seconds to decide what to do, and two seconds to do it."[13] When in doubt, they safed the vehicle to prevent a catastrophic failure. The network faced the possibility of losing a satellite and its critical national security information; the AFSCF needed people who knew how to operate the system.[14]

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[12] S. Weems, *Augmented Satellite Control Facility Description*, System Development Corporation, 1 April 1963, 23, DTIC, AD404800.

[13] Patrick O'Toole, electronic mail to author, SUBJ: "Answers to your Questions," 11 Sept. 2001.

[14] Lt. Col. A. W. Dill, USAF, and Niall E. Tabor, Lockheed Missiles and Space Corporation, "Requirements Cycle for USAF Satellite Control Facilities," in *Proceedings*

In April 1959, the Air Force Satellite Control Facility did lose a reconnaissance satellite. DISCOVERER II successfully reached orbit, in the correct orientation--tail-first--and stabilized in all three axes, the first satellite ever three-axis stabilized. The test plan called for an automatic reentry but the satellite orbited too low. As DISCOVERER II passed over Kodiak, a controller entered the sequence to reset the timer on the automatic reentry counter. The console erroneously showed that he had sent the wrong command, so he reentered the command sequence. Then, under time pressure, he forgot to press the "Reset" button, and the new commands entered the vehicle, which added them to the old ones, locking out any further attempt to communicate. On April 14, one day after launch, the capsule ejected from the vehicle, and came down not in the warm Hawaiian "ballpark" where C-119 pilots waited to snatch it from the sky, but on snowy Spitzbergen Island, north of Norway, where Sergei Khrushchev, son of the Soviet premier, later confirmed that the Soviets had recovered it for Sergei Korolev's design bureau.[15]

Lockheed and Philco had built the satellite command and control system for a single satellite program, CORONA, including in the design several ground stations and the control center, meaning they only needed a simple design. As other satellite programs matured, the air force and its contractors augmented the network with satellite-

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of the IAS National Tracking and Command of Aerospace Vehicles Symposium, 43-45.

[15] Richard Sweeny, "Discover II Orbital Attitude Controlled," *Space Technology* 2 (July 1959): 26-27; Day, *Eye in the* Sky, 52-53; Peebles, *Corona*, 66-67. According to Peebles, this mission was the source for Alistair McLean's novel *Ice Station Zebra*, in which Americans and Soviets raced to recover a Soviet reconnaissance satellite that came down in the Arctic carrying film of American missile silos. For more on the Soviet space program, see Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space race, 1945-1974* (Washington: NASA, SP-2000-4408, 2000).

specific equipment for those programs, adding even more stations and equipment, in many cases just as a quick fix. Therefore, an important aspect of systems engineering became planning the future Air Force Satellite Control Facility's configuration, with the goal of offering adequate support to all air force satellite programs. At the same time, the systems engineers tried to simplify operations and maintenance by making engineering tradeoffs between simple subsystems with a minimum of interconnections and complex subsystems with a large amount of automation.[16] As reconnaissance from space became an increasing national priority during the Cold War, the air force needed the AFSCF to handle multiple satellites in real-time.

Future multiple on-orbit satellites stood to complicate operations for the Air Force Satellite Control Facility. By 1961, planners understood that the AFSCF might reach a saturation point, both for personnel and for equipment, because of the increasing number of satellites on-orbit simultaneously. The factors causing operational difficulties like the DISCOVERER II failure would only get more exacerbated as the heavens filled with satellites. The solutions proposed included more equipment standardization, a unique operating frequency for each satellite, and further augmentation of existing facilities.[17]

Just fulfilling operational requirements became so difficult as the number of satellites on-orbit increased that system requirement planning even became too much for the AFSCF to handle. Colonel Walter R. Headrick, Jr., director of the Air Force satellite

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[16] Richard G. Stephenson and R. C. Hansen, "Aerospace Corporation and Satellite Control Engineering," in *Proceedings of the IAS National Tracking and Command of Aerospace Vehicles Symposium*, 50.

[17] Dill and Tabor, "Requirements Cycle for USAF Satellite Control Facilities," 45-46.

control project at Los Angeles Air Force Station, recognized the need for a separate office in charge of research and development in tracking station equipment configuration and procedures. Without standardized procedures facility-wide, the whole satellite command and control system could quickly be degraded. To prevent this problem, the air force needed scientific and technical assistance to help in planning and evaluating new ideas, designing systems, evaluating contractor proposals, and monitoring program progress.

In 1961, Colonel Headrick asked Aerospace Corporation to establish a Satellite Control Office to provide general systems engineering and technical direction support for the AFSCF. Aerospace Corporation had a senior engineering staff that possessed unique technical competence in the fields of instrumentation, computer applications, antennas, space communications, and data processing, which the air force did not have among its engineers. Headrick appealed directly to Dr. Ivan Getting, Aerospace Corporation President. Aerospace Corporation set up an office in the Palo Alto area under Dr. Ezra Kotcher to accomplish system engineering and technical direction (SE/TD). In October, Aerospace Corporation established a Satellite Control Office under Stanley D. Crane at El Segundo, near Headrick's satellite control program office. A few months later Richard G. Stephenson succeeded Crane, continuing in this position until November 1965. These civilian engineers helped the air force create a unified satellite support facility capable of rapidly and efficiently expanding to support the rapidly increasing military space program.[18]

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[18] *Aerospace Corporation*, 124.

To achieve this new satellite command and control system concept, Aerospace Corporation's Satellite Control Office conducted a series of engineering analyses. During its first nine months of operation, the Satellite Control Office evaluated ideas about various subsystems to meet near-term support requirements. It also continued support of current operations identifying and solving immediate problems. Most important, the Satellite Control Office developed a satellite support system concept flexible enough to accommodate the support requirements of all satellite programs, present and future. Engineers determined the existing support requirements and capabilities, trying to forecast future program requirements and instrumentation support capabilities. In the process, the staff conceived of a system that not only could support current programs but that could expand to accommodate the more sophisticated satellites of the future, assuming the increased sophistication would result in increased data transmission rates and position measurement accuracy as well as longer satellite operational lifetimes.

In January 1962, the air force contracted System Development Corporation of Santa Monica, California, to review every aspect of the Air Force Satellite Control Facility in a series of studies. They evaluated the capabilities and conditions of the existing systems and subsystems, existing and planned workloads, and expenditures and requirements. They tried to assess the ability of the AFSCF to support the assigned load, but focused particular attention on 1963-1965 when the air force planned to bring on-line the MIDAS and SAMOS missile warning and observation programs. Their plan supported multiple satellite operations for extended periods by standardizing the

configuration of station equipment and by implementing system-oriented methods for data handling and control.[19]

System Development Corporation concentrated its new concept on multiple satellites and real-time supports, which required that the Satellite Test Center in Sunnyvale and all remote tracking station systems be simplified and standardized. Aerospace Corporation presented the detailed concept to the air force in early 1962. They tried to ascertain the most cost-effective way to integrate new equipment, capabilities, and methods with existing ground systems and spacecraft. Aerospace Corporation documented the results and submitted them to Colonel Headrick for policy and management review. After acceptance, the Air Force Statement of Work comprised the Request for Proposal for the aerospace industry, forming the basis for the first major upgrade of the AFSCF, a new program known as Multiple Satellite Augmentation. Known by the acronym MSAP, most people called it simply "Augie." The air force approved MSAP in April 1962 but, due to funding limitations, divided the program into two phases, MSAP-A and MSAP -B.[20]

Aerospace Corporation also planned a second upgrade program, called the "STC Interim Expansion." This program included the Advanced Data System project involving new software for the Air Force Satellite Control Facility and a new communications system called EXCELS. Aerospace Corporation saw the standardization of frequencies and satellite beacons as fundamental to all these upgrades. The defense department's

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[19] H. H. Jensen and R. G. Kramer, *Air Force Satellite Control Facility History* (El Segundo, Calif: The Aerospace Corporation, 1969), 2, Report No. TOR-0066(5110-01-)3, AFSPC/HO, Box 7-2-1.

[20] *Aerospace Corporation*, 124.

standard telemetry, command, and control system, called the Space-Ground Link Subsystem, grew out of the Unified S-band system that Dr. Eberhardt Rechtin and others at NASA's Jet Propulsion Laboratory had developed between 1954 and 1964.[21] The air force implemented most of Aerospace Corporation's plans, resulting in vast numbers of hardware and software changes.

By the end of the Multiple Satellite Augmentation Program upgrade, the Air Force Satellite Control Facility consisted of a central control station called the Satellite Test Center (STC) and six remote tracking stations, three of which could control two satellites at once. The STC had enough computers and operations areas to control six satellites simultaneously, dividing the data processing subsystems into two main areas: the "bird buffer" complex had eight Control Data Corporation CDC 160A computers, a fully transistorized, stored-program, general purpose computer, each with a 32K core memory, individually assigned to an active satellite and acting as a data handler between the STC and the remote tracking stations; the other computer complex used four CDC 160A computers to do the main computational chores for the entire system. Computer-controlled switches connected the "bird buffers" with the CDC 160As on one side and the tracking station computers on the other. Each CDC 160A computer, "a flexible, multipurpose computer constructed in a standard-size office desk," stored program data, processing and converting them using high-speed transistorized circuits.[22]

[21] See Koppes, *JPL and the American Space Program.*

[22] Weems, *Augmented Satellite Control Facility Description*, 1-2, 17.

At the tracking stations, three main equipment groupings dominated. The antenna subsystems consisted of a sixty-foot antenna, providing communications between the vehicles and the ground. The data processing subsystem included two CDC 160A computers, one for telemetry processing, and one for tracking and commanding, handling data going to and from Sunnyvale. The telemetry, tracking, and commanding subsystem passed data between the antennas and the data processing computers. Manual patch boards connected the three equipment groupings, giving the tracking stations a lot of flexibility, but also offering many opportunities for manual errors.[23]

Unfortunately, the Multiple Satellite Augmentation Program installation did not go smoothly everywhere in the network. On 17 July 1963, a Western Development Laboratory (part of the Philco Corporation) engineer under contract for the installation project attempted to balance the synchro cables from one building to another. When he reinserted the plugs, a white flash of smoke emanated from the cable termination cabinet. Instead of connecting them, he shorted out all the leads to the junction box. The unit historian recorded that a check revealed that a cabinet cross-connected for the final configuration. Operations personnel spent the next eight hours repairing the cable. The outage precluded the use of the station for one operational support, causing the potential loss of a satellite. "Too many fingers in the pie," wrote the unit historian.[24]

Despite the problems during installation, the MSAP created a new multiple satellite capability and for the first time, a real satellite control network. In late 1962,

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[23] Ibid., 17, 23.

[24] *History of the 6594 Aerospace Test Wing*, 1 July-31 Dec. 1962, Appendix 3, 8, AFSPC/HO, Box 3-3-2.

New Boston began continuously performing multiple satellite support operations involving as many as five different types of satellites on orbit at the same time, a far cry from the one satellite on orbit every four or five weeks. The peak load consisted of four actual operations and one launch rehearsal. Each of the three crews on eight-hour shifts around the clock frequently tracked two satellites simultaneously passing over the station. As they did so, time to get the station ready for its next satellite support operation shrank, requiring crews to be increasingly proficient in the subsystems. In short, station activities increased during this period from providing support to an occasional satellite to that of supporting multiple satellite operations continuously.[25]

In sum, the Air Force Satellite Control Facility overcame the technological challenge of supporting multiple on-orbit reconnaissance satellites by reengineering the command and control system to handle increased requirements. The Multiple Satellite Augmentation Program tied the AFSCF tracking stations together as a real network from what had been a group of unique remote command and control stations bound together in a military organization. Nevertheless, when the experts could not correct the challenge presented by a new satellite program with different needs within the context of the existing system, the problem became a radical one, bringing about a new and competing system of satellite command and control.

Program II

The air force launched the first weather reconnaissance satellites in the early

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[25] Ibid., Appendix 7, 2.

1960s. Program II, as the National Reconnaissance Office first called the system to mask its weather reconnaissance mission, depended for its first year of operation on the ground stations that Col. Thomas O. Haig, weather satellite program manager, had originally helped develop for CORONA. Haig's challenge in the NRO was to overcome the major difference between CORONA and the weather satellite program: CORONA vehicles only orbited for about three days and then returned their film, while the batteries on the remaining Agena booster died; the weather satellites, which did not deorbit film but transmitted data, stayed operational and on-orbit for months. The tracking stations spent three or four weeks of endless rehearsals getting up to a maximum effort for a CORONA launch, but only had a few minutes to get ready for each support of a weather satellite. The system Lockheed initially built for CORONA did not have a capability to make rapid changes or to support multiple satellites.

After a CORONA mission, successful or not, the tracking stations all shut down and everybody went away. CORONA launched, on average, about once a month, and the early successful vehicles only lasted about seventeen ninety-minute orbits. The weather vehicles, on the other hand, came around two or three times a day at every tracking station, downloading weather telemetry data each time, meaning the stations had to stay staffed and operating continuously, not the way Lockheed originally planned to operate the satellite command and control system. The weather program, despite its usefulness for prioritizing picture-taking for CORONA operators, disrupted the normal operations of the Lockheed-built tracking network. Additionally, Lockheed had no interest in the weather satellites because RCA built them. The Lockheed-run tracking stations, to

paraphrase Colonel Haig, gave the weather program terrible support. They only supported about half of the times when the weather satellites came overhead, missing a lot of useful weather readout. The weather satellite operators never knew for sure whether commands had actually gotten to the satellite until long afterwards when Lockheed reluctantly sent a message by teletype: "We got it" or "We didn't get it."[26] This inability to serve satisfactorily another program cost the Air Force Satellite Control Facility a potential customer. The weather satellite program simply built its own command and control network. The implications for satellites, in general, were vast.

Colonel Haig, as manager of Program II for the National Reconnaissance Office, constantly traveled to Sunnyvale to berate people about his program, always starting with Lt. Col. ("Moose") Mathison, the on-site commander. Together Haig and Mathison went over and talked to the Lockheed engineers and managers, who listened, but ignored him. According to Haig, he did not get much response from them because the weather satellite program "annoyed" Lockheed. Eventually, Under Secretary of the Air Force Dr. Joseph Charyk, the director of the NRO, issued an order that "Lockheed will support this program, period." Still, it took a long time for the order to get down to the people at the stations.[27]

When the second year of operation began, Charyk told Haig to extend the weather satellite program. Haig went back to Lockheed to get an estimate of the cost for another year of command and control support. Using the Sult formula, Lockheed suggested a

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[26] Haig, *Quest* interview, 55.

[27] Ibid.

cost that would have consumed more than three-fourths of the total weather satellite budget, even before Haig had bought boosters and satellites. At that point, Haig and his team spent two weeks of frantic effort designing their own ground stations and control center, using parts of equipment from the Eastern Test Range, locating them on the island of Eleuthera. They put together a proposal, then went in and got Charyk's approval to go ahead. For about twenty percent of what Lockheed wanted to charge them for one year's operation, Haig's team built and equipped the ground stations and the control center for the weather satellite program. Moreover, they did it all in less than six months. Charyk later described his ideal program manager as a "kind of guy who, first of all, has a strong grasp of basic management principles, who has the energy and drive that goes with it, and [has] either the feel for the technical aspects of it, or [has] the good sense to know where to go to get it, that produces the best situation."[28] Charyk could have been talking about Tom Haig.

The weather satellite program had to depend upon the Lockheed ground stations, and the Air Force Satellite Control Facility, which Lockheed primarily operated, did not satisfy Haig. The fledgling AFSCF could not manage the two secret reconnaissance satellite programs, CORONA and the weather satellite, at the same time. They could do either, but not both. In case of a conflict between a CORONA satellite and a weather satellite, Lockheed and the AFSCF always paid attention to the CORONA satellite, which Haig understood, knowing about CORONA's reconnaissance mission. The four hours the ground stations spent testing and configuring equipment before and after a

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[28] Joseph V. Charyk, interview by James C. Hasdorf, 15 Jan. and 24 April 1974, Washington, DC, 78, AFHRA, K239.0512-728.

CORONA support operation exasperated the AFSCF's other potential customers. Those processes seemed wasteful and inflexible, but Lockheed insisted on it as "preparation time." For Haig, the contractors seemed very difficult to work with, even though the weather satellite program did not have a contract directly with Lockheed. Instead, Haig's program had to work through the AFBMD in Los Angeles. Lockheed did not have to pay a lot of attention to the weather satellite, so they often ignored it. To solve his tracking needs, Haig moved the weather satellites away from the Air Force Satellite Control Facility, creating a separate and distinct two-station command and control network for the weather satellites.

Later, when Haig moved to the NRO in the Pentagon, he made a recommendation to Alexander Flax, Deputy NRO Director, based on his experience with the weather satellite program, that began to "stovepipe" the various national reconnaissance satellite programs. Lockheed struggled with a great many technical difficulties, including conflicts between various satellites on orbit. In the early days of the Multiple Satellite Augmentation Program, Lockheed still had not learned how to support multiple satellites efficiently. Sometimes, the satellites came by at the same time, so operators had to choose one or the other, which meant one satellite did not get serviced, sometimes at a cost to national security when they lost information by not sending commands or receiving data. Haig suggested that the NRO should separate or "stovepipe" the satellites, that is, build a dedicated ground network for each satellite system, rather than building a consolidated network like the AFSCF. Flax recommended Haig's idea under his own signature, angering those in Los Angeles who feared an upset in the AFSCF

empire.[29] Dedicated networks like those in Haig's proposal may even have moved these programs into "blue-suiting" them much earlier. A simpler, dedicated ground environment seemed, at the time, much more sensible and, in fact, many reconnaissance programs developed a dedicated ground environment of some sort. The long-term implications of this trend, though, proved wasteful and problematic as the AFSCF performed its mission more efficiently, budgets shrank, and the Cold War ended.

To make matters worse for Lockheed, the weather program did all its systems development without a systems engineering contractor. Haig knew from his experience with the tracking stations in CORONA what a satellite ground station required. He also had one very smart, young officer, Capt. Lou Ricks, in the program office. Because they had a small program office, just four officers and a secretary, they moved fast and made decisions quickly. In addition, Haig did not report to anybody but the NRO director. Once a month, Haig made up his word charts and jumped on an all-night flight across the continent from Los Angeles to Washington, where he reported to the NRO director, got instructions, went back to Los Angeles and, then reported to Brig. Gen. Robert M. Greer, the AFBMD deputy commander. Haig often went up to Greer's office and gave him the same briefing he had given Charyk, plus all the instructions Charyk had given him.[30]

For a while, the weather satellite program operated sleekly and efficiently. According to Haig, Charyk and Brockway McMillan, Charyk's successor as NRO director, considered the weather satellite program as "sort of a toy." They used it to

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[29] Haig, *Quest* interview, 57. Flax also served as Chief Scientist of the Air Force, Assistant Secretary of the Air Force for R&D, and as NRO Director.

[30] Haig interview by author.

"tweak Lockheed's tail and to do battle with [Space Technology Laboratories], too."[31] That the weather satellite program succeeded extremely well with blue-suit operators "on fixed-price contracts without any Space Technology Laboratories involvement of any kind whatsoever was choked down Lockheed's throats many times." Said Haig, Aerospace Corporation chief "Ivan Getting considered me the biggest pain in the butt he'd ever had."[32] Every now and then, according to Flax, former NRO chief, someone in Congress or the Bureau of the Budget stumbled on the fact that the United States had two weather satellite programs, one NASA's Tiros and the other NRO's Program II. Sometimes the air force program ran ahead of the NASA budget, sometimes the other way around. The two organizations did not have common cost accounting systems, but the NRO, according to Flax, acquired their satellites "a hell of a lot cheaper than NASA's and they [NASA] said that was because we did our bookkeeping differently. . . ."[33] Even today, government accounting is certainly a mystery, but the NRO did its accounting in the black world of the national intelligence program, while NASA did its accounting in the public eye of the national space program, making comparisons tenuous at best.

The weather satellite program made direct contributions to ground station development. When he built the weather satellite ground stations, Colonel Haig, learning from working with the CORONA stations, overcame the necessity for a big bore-sight tower three to five miles away from the main antenna but within the receiving antenna's

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[31] Ibid.

[32] Ibid.

[33] Alexander Flax, interview by J. C. Hasdorff and Jacob Neufeld, 27-29 Nov 1973, Washington, DC, transcript, 132, AFHRA, K239.0512-691.

line of sight. The CORONA bore-sight towers stood far enough away from the receivers to cancel out any ground effect so that antenna operators could get a clear signal from a little transmitter up on the top of the tower. The operators pointed the antenna at the bore-sight to determine the true electrical vector, the true pointing angle for the simulated satellite, and then used the little transmitter on the tower to calibrate the receiving loop all the way through the antenna down to the receiving equipment. The expensive bore-sight towers stood up to 150 feet in the air, requiring a lot of real estate. Haig suggested that instead of using a bore-sight tower to determine the electrical axis of the satellite, they use the sun. Antenna technicians scanned across the sun in X and in Y, both directions, noted the edge of the sun in each axis, took half of that and, knowing their own latitude and longitude, used navigation tables to determine exactly where the antenna pointed at that time, thus calibrating the antenna. That method worked because the sun is a great emitter at all frequencies.

Haig also embedded a milliwatt transmitter in the base of the satellite dish, pointed it at the feed, hermetically sealed it and put a splitter on it so that half of the energy went to the antenna to be emitted and the other half went to a Bird Corporation wattmeter. Antenna technicians took the output of the Bird wattmeter and displayed it on a dial on the control console, telling the operator the strength of the emitted signal precisely, helping calibrate the complete receiving system through to the data recorder. That Haig innovation marked the end of bore-sight towers in the military. Radiation, Incorporated, the contractor putting together the 46-foot dishes, liked the idea so well they immediately publicized it when they sold their antennas. Radiation changed the

system from a hermetically sealed can, which proved too hard to do, to one that had a positive pressure in it by putting a little dry nitrogen bottle in it that lasted for twenty years. Haig also eliminated a requirement to check out the whole receiving link from the antenna feed all the way through the preamplifiers and the amplifiers and the transmission lines. The weather satellite program eliminated the need for bore-sight towers, and cut back system check out time, saving millions in the process.[34]

The ground network Colonel Haig built for the weather satellite program is important because it reveals in its differences that the AFSCF did not have to evolve in the way it did. Colonel Haig built a dedicated satellite command and control network for the weather satellite program because he had a particular mission to accomplish and a wide amount of authority in the early days of his program. By the time the weather satellite program reached a mature level for a space system, it operated in much the same way as any other air force space program. The Air Force Satellite Control Facility did not turn out the way it did because it was meant to; it turned out as a network of satellite command and control because the engineers who built it embodied it with political, economic, and social characteristics according to their own needs and experiences. Sometimes, though, a system's environment also presents engineers with interesting challenges.

Environmental Challenges

A technological system's environment is that part of the world that the system

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[34] Haig, *Quest* interview, 59.

cannot control. Another important influence affecting the development of the Air Force Satellite Control Facility in the early 1960s had to do with the location of the tracking facilities. The initial plan called for only four tracking stations. This geographical situation meant that satellite operators had contact with a vehicle on the first and second orbit and then no contact again until orbit seven or eight. Many events could and did take place during the "dead" revolutions. Analysts had a hard time figuring out what went wrong and when because the satellites did not have on-board recorders. The slight possibility that the Soviets could transmit to a vehicle and command it existed until the air force encrypted space communications in the late 1960s. In addition, Vandenberg could not track or record telemetry all the way to orbit insertion but only halfway to the burnout of the Agena booster. So even if all on-board systems looked good at data fade, plenty of opportunities for trouble lay ahead.[35]

Adding the station at New Boston and putting a tracking ship downrange off the Pacific coast of Mexico partially closed some gaps in coverage but still left a big hole in the entire Eastern Hemisphere. After extensive surveys in Southern Africa and the Indian Ocean, including the French island of Mauritius and a visit to Johannesberg, South Africa, on board *Air Force 2*, the Air Force Satellite Control Facility put a new remote tracking station on the Indian Ocean island of Mahe, in the British colony of the Seychelles. The air force dispatched a ship with station components, housing modules, new receiving and transmitting equipment, and the station tracking equipment. The ship arrived 1 July 1963 and the Seychellois hired to unload it unpacked an entire tracking

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[35] Frank Buzard, electronic mail to author, SUBJ: "AFSCF History," 12 Nov. 2000.

station's worth of equipment in just five days. The temporary mess hall and housing area reached operational status ten days later. They erected the antenna and station by the end of the month. Station commander Major N. H. Beaulieu declared the station "conditionally operationally ready" on 25 August. Teamwork, and the leadership of Philco Program Manager French Harris, and Ted Green, manager of the Installation and Checkout group, made this remarkable effort possible.[36] Air force and Lockheed leadership gave the people sent overseas to build the tracking stations a wide amount of latitude to get the mission accomplished, building a "First World" technological system in a "Third World" country.

Travel to and from Mahe also presented an interesting challenge. Nearly six hundred miles from land, the Air Force Satellite Control Facility operated the only airplane to Mahe until well after the Seychelles's independence from Great Britain. Beginning in September 1963, a Pan American International Airways HU-16B Albatross flew regularly between Nairobi, Kenya, and Mahe. The plane came in handy in December 1966 when Philco employee Martin Sheridan woke up unable to move his legs. After his admission to Victoria hospital in the island capital, doctors determined that Sheridan had Type I polio, the worst of the three categories (he had never received a vaccination). Station commander Major Donald E. Jensen and Philco Manager Harris quickly evacuated Sheridan on the HU-16B to the infectious diseases hospital in Nairobi, where doctors put him in an iron lung, returning with a load of vaccine for the local

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[36] *History of the 6594 Aerospace Test Wing*, 1 July-31 Dec. 1963, 8, AFSPC/HO, Box 3-3-1; A. Stormy Sult, electronic mail to author, SUBJ: "AFSCF History," 4 Sept. 2001.

Seychellois population.[37] In 1969, when a Philco employee died after hitting a tree in his car, the station tried to repatriate his body to the United States. Pan American, which had originally scheduled a flight to carry a critical spare part known as a klystron, rearranged its schedule on short notice to meet a flight in Kenya, returning the body back home.[38]

Isolation also worked to the air force's advantage. In 1969, following the Apollo 11 moon landing, the Seychelles featured an artist's depiction of the tracking station on a postage stamp, as part of a series showing the "standard, definitive . . . illustration of the Colony's history." The Seychellois expressed particular pride in their contribution to the moon mission. In the newspaper, they quoted "American authorities," most likely the station commander, as saying that "all station personnel, American and Seychellois, performed duties of importance that contributed to the success of the mission and can truly believe that they were part of the first launch that put man on the Moon."[39] In fact, during the mission the station tracked the air force's VELA satellites, used to detect the x-rays and gamma rays from space-based nuclear explosions, and served as a relay point for the NASA ARIA aircraft flying over the Indian Ocean. The station's location and its unique relationship with the local population partly contributed to its continued success, a relationship that continued for more than thirty years with some of the original personnel still there when the tracking station closed in 1996.

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[37] Major Donald E. Jensen, Commander, "Indian Ocean Station, Historical report," 1 July 1965-31 Dec. 1965, 3, in *Air Force Satellite Control Facility History*, 1 July 1965-31 Dec. 1965, AFSPC/HO, Box 3-3-2, Folder JD65.

[38] *Space and Missile Systems Organization History*, 1 July-31 Dec. 1969, Atch 2, 6, AFSPC/HO, Box 3-3-1, Folder JD69.

[39] Ibid., 8.

Like the Seychelles, the Thule Tracking Station benefited from its location in northern Greenland. Thule Air Base sits on territory leased from NATO ally Denmark and calls its officers club the Top of the World Club. To see the Northern Lights, residents have to look to the south. When the Air Force Satellite Control Facility built the tracking station in 1961, SAC already had a sizeable presence there. More than ten thousand personnel supported a B-52 bomber wing on airborne alert and a missile warning radar site watching for Soviet ICBMs that might be bound for North America. Although they allowed information about the nuclear mission of the NATO ally's base, the Danish did not want it known that the Air Force Satellite Control Facility had a station at Thule supporting reconnaissance satellites, for fear of the repercussions in international public opinion in the 1960s. The state department gave Denmark its assurance that there would be no publicity about the satellite tracking station. Under orders from the assistant secretary of defense, the AFSCF classified the presence of its satellite command and control site as confidential. In all unclassified correspondence, the air force referred to the station as Operating Location Number 5 (OL-5) or by the station's call sign, POGO. The base commander did not even mention the station's presence in his mission briefing.[40] The importance of the location in Greenland meant the station served nearly every orbit of every polar-orbiting reconnaissance satellite, leading the air force to upgrade equipment frequently and add antennas to Thule's tracking station.

The big secret that the air force had a satellite command and control site at Thule

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[40] F. Robert Naka, interview by author, Colorado Springs, 16 June 1999.

did not remain a big secret for long. On 20 May 1964, NBC's Huntley-Brinkley evening newscast mentioned the Thule site and even showed a picture. Later in 1964, the Army Corps of Engineers put out a call for bids on a project bearing the title "Thule AB, Tracking and Telemetry Station," and the base phone book listed the site as "Air Force Satellite Control Facility (OL-5)." The twelve hundred Danish nationals, the four hundred monthly visitors to the base, and the rest of the base population could not all be counted on to keep the station or its mission a secret, nor did the United States keep its active reconnaissance satellite program a secret by the mid-1960s. With the help of the state department and the Danish Foreign Ministry, the AFSCF quietly declassified its reconnaissance satellite operations at the Thule Tracking Station in 1969.[41]

Geography did cause problems for the AFSCF that the air force overcame with leadership and improvisation. Distance and a lack of communications satellites meant the service had to use high-frequency tropospheric scatter radio links to connect the farthest stations with Sunnyvale. The Indian Ocean Station had a microwave link to Cape Canaveral through Ascension Island in the South Atlantic. From stations equipped only with a microwave link, like INDI, Sunnyvale could not get instant receipt of telemetry data, which controllers needed to make split-second decisions about a satellite. If a controller wanted to talk to the stations, they communicated either by teletype or telephone. For Thule, the tracking station "on top of the world," telephone connectivity to the United States over the North Atlantic submarine cable only worked intermittently

[41] Collection of documents on the Thule classification debate from 1964 to 1967 AFSPC/HO, Box 3-5-2. All correspondence after 1969 refers to the station as the Thule Tracking Station.

at best. Since activation of the circuit in February 1962, on two separate occasions something or someone broke the submarine cable out of Thule. The air force assumed Russian trawlers cut the cables, although someone suggested that icebergs might have been responsible. When the cable went out, the station rerouted the circuit over the "tropo-scatter system," which used a signal bounced off the troposphere, but the inherently unreliable tropospheric circuit could not support the 1,200-bit data rate the station needed for some of the satellites it supported.[42] Moreover, as the sun approached solar minimum in 1964, tropospheric scatter methods grew even less reliable because the atmosphere shrank.

The AFSCF brought the communications problem to the attention of the Defense Communications Agency (DCA), which the army controlled. Thule's communications priority rested right behind the Ballistic Missile Early Warning System (BMEWS) in importance, but DCA told the AFSCF that the only real solution to the problem would be a satellite-based communications circuit, which would not be available for at least a year, forcing the AFSCF to accept the situation. By 1964, the Thule to Cornerbrook, Newfoundland, submarine cable experienced six to eight breaks a year, "caused by icebergs or fishing trawlers." Each cable break required at least a week to repair and became a part of doing operations for Thule until the army, which had responsibility for satellite communications channels because it administered the DCA, established satellite

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[42] *History of the 6594 Aerospace Test Wing*, 1 Jan.-30 June 1962, 5, AFSPC/HO Box 3-3-1.

communications links.[43]

The natural environment surrounding the AFSCF, a worldwide organization with twenty-four hour operations, affected more than just communicating data back to the customer. Two major events occurred at the Kodiak Tracking Station in 1964 that illustrate just what the effect of the environment could be on technology: the 27 March earthquake and tidal wave, and the modification of the station to accommodate the Multiple Satellite Augmentation Program.

The 1964 Alaskan earthquake, the largest in history, reached nearly 8.5 on the Richter scale and lasted more than two minutes. The quake's fault line ran only about two miles east of the Kodiak Tracking Station. During the month and a half after the quake, two hundred strong aftershocks followed, some with a 6.4 magnitude, causing many people to leave Kodiak for the Lower-48. The three tidal waves, which occurred during the first few hours after the quake, caused most of the damage and deaths. A williwaw, a type of high wind, arose two days after the quake, destroying the local fishing fleet because the quake and tidal wave had destroyed the sea wall around the small harbor in Kodiak.

Lyle Burnham was running operations for Lockheed at the site when the quake hit, at about 1730 on Good Friday. The controllers had just finished a satellite support operation and had no more scheduled for some time. Someone commented on the

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[43] *History of the 6594 Aerospace Test Wing*, 1 July-31 Dec. 1964, 2-3, AFSPC/HO, Box 3-3-2. To make matters worse, the Syncom communications satellite fell behind schedule and did not meet its initial operational capability until late in 1964. See Donald H. Martin, *Communications Satellites, 1958-1992* (El Segundo, CA: The Aerospace Corporation, 1991), 12-14.

unusually beautiful and serene evening. Most of the "brown baggers," married personnel who lived in Kodiak, had left the site and headed to town when the quake struck, leaving few people on the tracking station. The power went off due to a broken diesel fuel line, which shut off communications with the outside world, but power came back on in about twenty minutes. The tracking station itself survived relatively undamaged, although the supply storeroom required several days to clean up.

The tracking station got off relatively lightly, but the same could not be said for the nearby village of Chiniak. For several days after the quake, the site had only ham radio and citizens band (CB) radio to communicate with the village of Kodiak. Station maintainers quickly restored the normal phone lines to the Satellite Test Center in Sunnyvale. The station handled several hundred phone and teletype messages from Kodiak residents to their friends and relatives in the Lower-48, because the quake destroyed the phone lines out of Kodiak. Local pilots, some of who worked at the tracking station, brought messages by plane from the village out to the station, where they were keyed into the military teletype circuits to Sunnyvale. Some emergency messages also went out by Leroy Witlach's ham radio. Witlatch manned his radio continuously for several days until he almost dropped from exhaustion.

A month or so later, some of the Chiniak crew formed four-wheel-drive-vehicle parties, usually with large, low-pressure tires. They put temporary road repairs in spots so they could travel back and forth to Kodiak at low tides. Groups usually of three or more made the Kodiak trip at low tide until the road opened for normal traffic in mid-December 1964. Some road trips took place after midnight to take advantage of the tides.

Recalled Burnham, "The unique thing I found after the quake was how everyone worked together to get things accomplished. The brotherhood of man was highly demonstrated after the quake."[44]

The earthquake also affected the major system upgrade for the Kodiak station. The air force had awarded the Multiple Satellite Augmentation Program modification contract with an estimated completion date of 21 November 1964, basing the date on road transportation from the town of Kodiak to the site, but the tidal wave after the earthquake wiped out the road. By 1 July 1964, it had become very evident that sea and air transportation could not deliver construction equipment and materials to meet the completion date due to weather conditions. Although the road became passable about the start of November 1964, the installation schedule slipped, resulting in construction not totally completed by the end of the year.

The lack of a road not only hampered the construction program, it also affected the support and operation of the station. While the road lay under water, the station depended on the navy for sea and air support, which did not always permit prompt delivery. Once the station went without gasoline for three days; another time the station got down to one day's supply of meat. Throughout the period without a road, personnel commuted to visit families in town with the local bush pilots. On several occasions, wind and poor visibility stranded station personnel for two- and three-day periods. Finally, accommodation of the construction and installation personnel by the station meant overcrowding in the mess hall and in the sleeping quarters. In addition, the support

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[44] Lyle Burnham, http://linux.kib.co.kodiak.ak.us/kmxt/af_track/bob.html, accessed 19 July 2001.

contractor added twelve to fifteen extra personnel to support the station during the construction and installation. Throughout all this upheaval, station morale remained high but everyone looked forward to going operational with the new Multiple Satellite Augmentation Program system.[45]

Environmental problems also forced Hawaii Tracking Station personnel to adapt. Only one access road led to the station, Farrington Highway, passing through the Makua Valley. Periodic heavy rainfall flooded portions of the road in the valley, but station personnel crossed the flooded areas using an army truck. On the morning of 23 December 1964, the water remained so high and rapid that even the army vehicle could not pass the flooded sections of the road. A helicopter from Hickam AFB dropped emergency rations to the station personnel so they could eat. At 1515, the swing shift finally relieved the night shift, which had arrived for work at 0045.[46]

A technological system can control only a part of its environment. An open technological system is one subject to the influences from its environment, and a closed system is one that not subject to those influences.[47] Clearly, the AFSCF was an open system, subject to a wide range of influences in the physical environment, as well as the economic, political and bureaucratic environments. Just as important as the technological and organizational challenges of the AFSCF's growth, the environmental challenges the

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[45] *History of the 6594 Aerospace Test Wing*, 1 July-31 Dec. 1964, 93, AFSPC/HO Box 3-3-2.

[46] Ibid., 168.

[47] Hughes, *Networks of Power*, 6.

manager-entrepreneurs dealt with during construction and the early years of operation affected the technological style of the entire satellite command and control system.

Summary

Challenges arise in technological systems, sometimes without warning. They can be organizational or technical, or something entirely different and outside the system's control, such as its environment. Today, problems continue in the AFSCF as they do in all large technological systems, but none loom as large as the challenges conquered in the early 1960s. The AFSCF overcame the technological challenge of supporting multiple on-orbit reconnaissance satellites by designing a system that could handle the increased requirements. Known as the Multiple Satellite Augmentation Program, the new technology turned the AFSCF into a real network for the first time instead of a grouping of unique remote command and control stations bound together in a military organization. Within MSAP, engineers tried to overcome equipment interface problems, facing still other challenges within proposed solutions.

Finally, during this period that it overcame challenges in its evolution, the Air Force Satellite Control Facility also built technical and organizational momentum that the system later used to keep customers away, an unusual choice for a large enterprise. Managers tried to overcome momentum by introducing a new technology, the Space-Ground Link Subsystem, which made the AFSCF essential for every satellite program in the Department of Defense and valuable for some NASA programs as well. At the same time, the air force used the Space-Ground Link Subsystem to overcome the momentum building up in the large numbers of personnel still required to operate the older MSAP

system. The Space-Ground Link Subsystem, conceived of in 1963, finally made the Air Force Satellite Control Facility a common-user network, with the ability to serve every American satellite program in development.

The AFSCF took an important step in its evolution into a satellite command and control system in this period, doing so in support of the rapidly evolving satellite reconnaissance programs. Engineers devised plans for the long-range implementation of a unified, general-purpose satellite control network, a plan that changed the relatively simple Subsystem H of the CORONA program into the multi-user AFSCF that eventually supported most military space programs. Today, the air force's satellite control network to some degree supports even those programs that have dedicated support facilities like the Defense Support Program. A complex team of air force officers and enlisted, contractors, and government civilians, undertook the project, designed to meet immediate requirements while simultaneously planning for the future.

CHAPTER 5

"UNBOUNDED FAITH": THE TECHNOLOGICAL STYLE OF THE AIR FORCE SATELLITE CONTROL FACILITY

> The pace is not set by technology, General Schriever declared, it is set by management. Brain power must replace manpower. And even the manpower available to [Air Research and Development Command] has shrunk, he said. It all added up to close cooperation of the military-industry team to win the technological war.[1]
>
> -- *The Airman*, February 1961

> The salient feature of the manpower crux is a bare minimum of three crews and a steadily increasing workload [*sic*].[2]
>
> -- Unit Historian, 6593d Range Instrumentation Squadron, June 1963
> New Boston Air Station, New Hampshire

When the United States Air Force began studying satellite command and control, very few people had any idea how to track a satellite or predict an orbit. The mathematical model for calculating orbital parameters, known as an ephemeris, remained a matter of great mystery. One Lockheed programmer finally developed the computer software for taking antenna tracking angles, developing an ephemeris, and then pointing an antenna at a satellite. Retired air force Col. Thomas O. Haig called the program "the most monstrous pile of punched cards." This engineer patched and repaired the software so many times the total number of cards sent through the computer ran "four or five

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[1] Blair, "From Saddles to Satellites," 12.

[2] *History of the 6594th Aerospace Test Wing*, 1 Jan.-30 June 1963, 9, AFSPC/HO, Box 3-3-1.

times" the number actually needed. Most of the cards patched and repaired the software, but if the computer operator did not run all the cards, the program would not work. Lockheed only had this one resource for giving directions to antennas and developing an ephemeris. Then shortly before the first CORONA flight in late 1959, the engineer resigned from Lockheed, which then had no way to track a satellite, an important aspect of its contract with the air force. Lockheed officials panicked and went after him, eventually hiring him back as a consultant at "three or four times" what they paid him before as a Lockheed employee. According to Colonel Haig, the programmer now only had to load the cards in the proper order. "Then, when he was through running the program, he would squirrel the cards away and screw up the order so nobody else could do it."[3] No one, therefore, should doubt the importance of a single human being in the development of new technologies. Just as important as the role of people in technological systems' development, this particular event in the evolution of the Air Force Satellite Control Facility illustrates its early technological style: engineers cobbled together a hodgepodge of systems for a higher purpose, never doubting their ability to make it work.

No discussion of the evolution of the air force system of satellite command and control would be complete without a look at the technological style that developed in the Air Force Satellite Control Facility. Technological style is an important topic because system builders, like artists and architects, have creative latitude, and so did the developers of the AFSCF. No one best way existed to develop an ideal satellite control

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[3] Haig interview by author.

network, just as no one best way exists to paint the Last Supper or to build the Taj Mahal or to write a computer program for calculating orbital elements. One look at the distinct and separate networks that the reconnaissance satellite program and the weather satellite program each developed unmasks that myth.

A careful examination of the Air Force Satellite Control Facility's technological style also helps further defeat the idea of technological determinism.[4] In light of the 1961 Vostok I success (Yuri Gagarin's single-orbit flight), a "psychological victory of the first magnitude," President Kennedy dramatically pushed to get to the moon "before this decade is out," not for military reasons, but in order to gain prestige for a stunned nation and his rocky presidency.[5] When Colonel Haig cancelled the Lockheed plan to install a three-dimensional projection system in the Satellite Test Center, he thought the system would be "a useless display for decision-making."[6] Haig's observation comments on technological style. Using technological style comparatively assists in the search in different constituencies for an explanation of the different characteristics of a particular technology.

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[4] For more on the idea of technological determinism see Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge: MIT Press, 1999); Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge: MIT Press, 1977); and Langdon Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago: University of Chicago Press, 1986).

[5] See John M. Logsdon, *The Decision to go to the Moon: Project Apollo and the National Interest* (Cambridge: MIT Press, 1970); Roger D. Launius and Howard E. McCurdy, *Spaceflight and the Myth of Presidential Leadership* (Chicago: University of Illinois Press, 1997); and McDougall, *...the Heavens and the Earth*, esp. 307-324.

[6] Haig interview by author.

Historical experiences also shaped technological style. During the lean budget years following the Korean War, research and development emphasis in the United States concentrated on preventing an all-out surprise Soviet attack on North America and on the development of weapons capable of massive retaliation.[7] Therefore, in the 1950s, the satellite command and control engineers planned for just a few flexible satellite tracking stations, even though the days of lean budgets for the military missiles and space programs had ended. In addition, the lessons of World War II, in which the United States did not have an initial cadre of well-trained individuals to fight a world war, explained the air force desire to keep trained a cadre of uniformed satellite operators. It also explained the willingness of the air force to contract out services as quickly as it did.

All of these elements contributed to the technological style of the Air Force Satellite Control Facility. Thus, in studying these subjects, we can make closer observations of how human beings constructed and shaped the AFSCF, thus infusing it with a mass of technical and organizational components that created momentum in the system.[8] Momentum, a term in physics, characterizes the motion of any object. It is the product of the mass of a moving particle multiplied by its linear velocity. A vector quantity, momentum has both magnitude and direction. The total momentum of a system made up of a collection of objects is the sum of the entire individual object's momenta. One of the largest sources of momentum in the AFSCF was the people who made it work.

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[7] See Redmond and Smith, *From Whirlwind to MITRE*, especially pp. 41-43; and Hughes, *Rescuing Prometheus*, especially 15-67.

[8] Hughes, "Evolution of Large Systems," 69-70, 76.

People Made It Work

Working with a one hundred bit-per-second teletype circuit, a phone line, and a sixty bit-per-second secure teletype circuit, the satellite controllers at the Satellite Test Center in Sunnyvale conducted operations in the "Interim Control Center" because no target dates in the construction of the Control Center had been met.[9] At the core of satellite operations, leased commercial circuits linked the Satellite Control Room to the tracking stations throughout the Pacific.[10] The satellite command and control operation, as technical as any in the aerospace industry at the time, relied heavily on people to make the technology work.

To make all the technology work as a system, the government and its contractors found a good working relationship essential to the development of the military space program. In the case of the air force's satellite command and control network, the prime contractors, Lockheed and Philco, competed every step of the way. Complicating matters, the air force experienced an ambivalent relationship with its contractors because of uncertainty about how much dependence to have on contractors. The 6594th Test Wing (Satellite) and a team of Lockheed contractors, who actually operated the missions, conducted each DISCOVERER mission under joint responsibility. In 1960, contractors outnumbered air force personnel by two to one, although the air force's goal of every job

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[9] *History of the 6594th Test Wing (Satellite)*, 1 July-31 Dec. 1960, 1-7.

[10] *History of the 6594 Test Wing (Satellite)*, 1 July-31 Dec. 1960, 22, AFSPC/HO, Box 3-3-1.

performed by a military member, not a contractor, began a shift in that ratio. Major General Ritland spelled it out in the 6594th's mission statement:

> The 6594th Test Wing is directed to...
>
> d. At the earliest practical time, develop the capability to man and operate, with military personnel, the command, control, engineering data processing and computing facilities associated with the Satellite Test Annex at Sunnyvale, California.
>
> e. At the earliest practical time man, operate and support the following tracking and acquisition stations with military personnel:
>
> (1) Vandenberg Air Force Base, California
> (2) New Boston, New Hampshire
> (3) Kaena Point, Hawaii
> (4) Donnelly Flats, Alaska
> (5) Other stations as may be designated[11]

If the organization realized this objective, the 6594th Test Wing would eventually number more than 2,000 military personnel.[12]

Lockheed personnel resisted integrating arriving air force uniformed technical personnel over "one major motivating factor--job security."[13] At the 6594th Launch Squadron at Vandenberg, contractors did not allow military technicians to perform satellite checkout tasks before launch. When the contractors needed help, they used military for "menial" tasks like wire pulling. During two strikes--at Convair, maker of the Atlas missile, from 6 June to 16 June 1960, and at Lockheed, from 15 June to 16 July 1960--military technicians effectively checked out and launched satellites, proving that the military personnel could take over from the contractors. When the strikes ended, the

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[11] Maj. Gen. Osmond J. Ritland, "Mission Statement," 6594th Test Wing, 29 Dec. 1960, AFHRA, K243.012-36.

[12] Russell Hawkes, "USAF's Satellite Test Center Grows," *Aviation Week* (May 30, 1960): 57.

[13] *History of the 6594th Test Wing (Satellite)*, 1 June-31 Dec. 1960, Appendix 5, 2, AFSPC/HO, Box 3-3-1.

military personnel returned to their previous observer status.[14] Eventually the relationship between the military and contractors smoothed out and air force technical personnel came under the direction of Lockheed supervisors.

At the New Hampshire station, activated 1 October 1959 to support MIDAS, air force officers arbitrated disputes and "closely" monitored activities because the complicated station management did run a smooth operation.[15] According to the contemporary unit history at the New Hampshire station, "positive Air Force management" stimulated improved satellite crew effectiveness and performance "beyond all expectation." Showing obvious bias, the air force historian concluded that this improvement "proved that Air Force management is far superior to contractor management."[16] The June 1961 official history described the "mutual cooperation of contractor and military personnel."[17] Clearly, personalities made a significant difference.

Despite the differences in personalities, contractors simply had more experience with the equipment, the biggest distinction between them and the military staff. In some cases, the on-console contractors built the systems themselves and remained to operate them. On one occasion, the operators at Kodiak waited for the first acquisition of a new satellite. The new vehicle came over the horizon on schedule and one of the technicians started the readouts. He announced the battery voltages, gas pressure, attitude, and

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[14] Ibid., Appendix 7, 11.

[15] *History of the 6594th Test Wing (Satellite)*, 1 Jan.-30 June 1961, Appendix 8, 2, AFSPC/HO, Box 3-3-1.

[16] Ibid., Appendix 7, 2.

[17] Ibid., Appendix 5, 7.

continued down the list. Then, as he watched, the values changed from those of a new, healthy vehicle to numbers of a satellite out of fuel, on weak batteries, and in a biased orbital attitude. (The Kodiak station had experienced angular coincidence with an older vehicle and the antenna operator had simply followed the best signal strength.) While the antenna operator had synchronous displays showing the predicted track, he waved the antenna about slightly to obtain the strongest signal. In this case, the closer, older satellite had a stronger signal, so he followed it instead. The VHF tri-helix had no autotrack capability and because they used the older FM/FM modulation, it had no phase-lock to keep it on the correct carrier. The decommutator operator quickly recognized the values as those of an older vehicle that Kodiak had tracked only an hour and a half earlier and knew he had a problem. When the information reached the back room, the control room team "launched their clipboards in panic" into the air. Precious seconds ticked by before they could get the antennas back onto the correct vehicle and then all returned to normal.[18]

Even experience could not speed up a relatively slow process. The tracking stations spent three or four weeks of endless rehearsals getting up to a maximum effort for a launch. Each satellite's own equipment configurations necessitated a lack of speed

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[18] Marv Sumner, electronic mail to author, SUBJ: "Re: AFSCN History," 5 Jan. 2000. "Several years later I was at the STC in Sunnyvale telling this story, and one of my listeners had been the System Controller on that pass. He clarified that they knew of the angular coincidence, but thought the older vehicle would have been passive." The same sort of event happened to the author while sitting on console for a DSP satellite support operation. A DMSP (weather) satellite, using the same downlink channel but orbiting at a far lower altitude (DMSP orbits at several hundred miles versus DSP at 22,500 nautical miles), passed under the author's DSP satellite and the antenna "walked off" to follow the DMSP vehicle. Immediately on the author's direction, the antenna operator at the remote site broke track on the DMSP satellite and reacquired the DSP satellite.

in satellite operations to get system configurations right the first time. If the trend continued, the Air Force Satellite Control Facility could end up with myriad receivers for a variety of satellites, each with its own peculiar operating characteristics. To alleviate part of the problem, Philco, the subcontractor for the ground stations, proposed designing a generic receiver, capable of operating at multiple input frequencies, which new satellite programs would have to operate within if they wanted AFSCF support. Using modular plug-ins and adjustments to meet specific program needs, the ground stations could all have similar receivers, even though their overall missions might be different.[19] This solution promised not only to save money, but also time.

The air force preferred to use airmen instead of contractors to operate and maintain the satellite command and control system. The service planned for officers with engineering degrees to launch and operate the satellites and enlisted people with technical training to operate and maintain the ground equipment. In the April 1960 edition of *Air Force/Space Digest*, General Terhune described the satellite operations in Sunnyvale. He described how the air force planned to do telemetry, tracking, and control at the remote tracking stations with staffs of NCOs, whom the air force considered similar to the airmen servicing fighters, bombers, and cargo planes. Civilian technicians would continue to do research and development, "but with operational systems, these jobs will belong to the men . . . and women . . . [sic] who wear Air Force blue."[20] To continue as the military space service, the air force planned to move ahead in the space operations

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[19] Philco Corp., *Multiple Satellite Control Facility Study*, 5 Jan. 1962, DTIC, AD452208.

[20] Terhune, "In the '*Soaring Sixties*,'" 71.

business with a core of space operations and maintenance personnel, all of whom wore blue uniforms.

Lockheed had a different idea about the staff for the tracking stations. The facilities requirements report for the New Hampshire station that Lockheed managers R. Smelt and R. A. Proctor signed in 1959 stated clearly that Lockheed wanted the station "operated, maintained, and supported by contractor personnel." Although the air force had to provide some facilities, like a building for the non-operations staff and a dining hall, permanently assigned contractor personnel could "obtain support from the surrounding communities [Manchester and Nashua, New Hampshire], thereby reducing this cost to the government."[21] Even before the first successful CORONA mission, the debate already had begun about who should operate Air Force Satellite Control Facility, contractors or airmen. The discussion over contractor or military staff would not be resolved quickly.

The air force had no uniformed expertise in operating and maintaining satellites, so the first air force officers joined contractors already on console in 1959. Forrest S. McCartney, now a retired air force lieutenant general, joined the air force space program in 1960, with two other air force captains, Mel Lewin and Al Crews, shortly after DISCOVERER II's loss in Norway. The air force assigned the three space operations pioneers to work for Lockheed alongside Lockheed employees. To conceal the true nature of their mission from the public, these young captains wore civilian business attire

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[21] R. Smelt and R. A. Proctor, "Base Support Facilities Requirements for the Northeast Development Operational Tracking Station," 17 April 1959, DTIC, AD802012.

as "somebody's idea of security." Recalled McCartney, "I kind of pushed back on it in the beginning, but it was at such an exciting time we didn't really have a big deal with [civilian clothes]."[22] Recalled Lewin, McCartney's carpool partner at the time and now a retired air force colonel, "I was so excited about what I was doing and enjoyed it a lot. It's not often you get in at the start of something."[23] People all over the Air Force Satellite Control Facility had that same feeling.

These officers paved the way for all air force satellite operators, using only their engineering training to get them going because no formal training program existed for any of the new satellite flyers, contractors or uniformed personnel. Three weeks after they arrived in Sunnyvale, that original group of captains had become the experts. Before actual flight-testing began, the captains worked only in the back room on the displays, supporting the Lockheed engineers on the consoles. The officer-engineers drew with grease pencils on acetate, putting viewgraphs up on screens or on closed-circuit television for the satellite controllers to see. Nobody knew anything more than the Lockheed employees did. The airmen's operational experience grew right along with the Lockheed employees. The captains did not have the technical expertise on the vehicle itself, but in terms of operational satellite control they essentially possessed as much expertise as the Lockheed people.[24]

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[22] McCartney interview by author.

[23] Lewin interview by author.

[24] Ibid. By contrast, the author went to school for four months before joining his operational Defense Support Program squadron, and then it was another month before he could run a satellite support without supervision.

To be fair, one could describe the early CORONA reconnaissance satellite system as the Model T of the satellite business. McCartney and company did not have all that far to go on the learning curve of this rudimentary system when they arrived in 1959. The first-generation CORONA vehicles only had four commands: reset, increase or decrease, and a "gray" command. Responding to a telephone call, a controller sent the order to the tracking station that sent the command to the satellite. The gray commands controlled the CORONA camera, although the operators, not cleared for the CORONA program, did not know it. Not knowing did not keep the officers from discussing the possible uses for the gray commands until the CIA eventually cleared McCartney, Lewin, and Crews for CORONA. According to McCartney, the trio speculated aloud too often and so the CIA briefed them to keep them quiet. Lewin recalled going over to the Lockheed Advanced Projects Facility in Menlo Park, the so-called "Northern Skunk Works," where they saw a CORONA vehicle under construction. "We were very impressed with how important we were at that time," Lewin said. McCartney later flew DISCOVERER XIV the night the CORONA camera took the first picture recovered from space; today a copy hangs on the wall in his office.[25]

The first CORONA vehicles required satellite controllers to have considerable situational awareness for a successful mission. A continuous, punched Mylar tape controlled systems on the vehicle so the satellite controller had to know what point the

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[25] Maj. Gen. Robert A. Rosenberg, USAF, Retired, telephone interview by author, tape recording, 21 Dec. 2000; Lewin interview by author; McCartney interview by author; MEMO, [Name Redacted], Colonel, USAF, Acting Chief, DPD-DD/P, to Deputy [CIA] Director (Plans), SUBJ: "Ground Controlled Commands Available in CORONA Prime Vehicles," 17 Aug. 1960, NRO, 2/E/0047.

tape had reached and what point the vehicle had reached in its orbit, all from hundreds of miles away. Controllers reset the tape and increased or decreased its speed to match whatever orbit the Thor-Agena combination happened to inject into, an imprecise feat at the time. In the early satellites, contractors put the tape together before launch because they knew what the targets would be. The Mylar tape had thirteen channels for the thirteen "fingers" that rode on top of the tape; when the contact went into one of the rectangular holes, it activated a relay and initiated a function. Using the tape, operators turned the receivers on or off, or the camera on and off, or the reset monitor, or whatever they needed to do. Adding to the challenge, and emphasizing the importance of situational awareness, the operators also had to take into account errors on the tape. Although the CIA mostly preplanned each mission, the success of the operation relied on the operators on console to synchronize the timer to get the satellite to operate the way the reconnaissance community needed it to perform.[26]

The CIA planned satellite reconnaissance missions weeks ahead of time, but found it an inefficient way to operate. Bad weather over the target area of the USSR or a vehicle anomaly could mean the camera took pictures of clouds, or worse, nothing. The CIA officer in charge in Palo Alto, Charles Murphy, tried to convince the Lockheed engineers to build a command into the satellite to give control of the camera to the operators in the Satellite Control Facility. "We finally got one command for the camera system, which was kind of a simple-minded thing, too. You could tell it to ignore the next hole in the tape or use the next hole in the tape. That's the way we turned the

[26] Lewin interview by author; McCartney interview by author.

camera on and off." To help preserve the most precious commodity on board the satellite (its 20 pounds of Kodak film), Lockheed gave the satellite operators some control over the payload by adding a few commands.[27]

But a simple system did not mean an easy one to operate. To keep a single controller from getting into too much trouble, they always worked in pairs, with one who sat as the primary controller and one who watched as the backup. At first, the air force officers always backed up the Lockheed controllers. Operations remained segregated, until the young officers displayed their capability to control satellites without contractor supervision. Lockheed had some concern, and probably the program office in Los Angeles did, too, because everyone easily tripped up during rehearsals and made mistakes. If someone made a mistake and a controller lost a vehicle, the implications could have been enormous, but no one ever did. The leadership quickly figured out that the airmen learned quickly and worked as proficiently as the contractors. Slowly, the military shifted over into the primary role for the satellite support operations, rotating the senior position among the three of them. Eventually they got to the point where they could operate as an all-military crew, with one primary and another backup, then switching seats.[28]

Not surprisingly, the young officers and their contractor comrades did not fit together like fingers in a glove. McCartney, for example, had a problem working for Lockheed. The contractors, not particularly hard to work with, looked upon the three

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[27] Murphy interview by author.

[28] McCartney interview by author.

officers "not as the customer so much as the competition." McCartney and company thought of themselves as more capable than the Lockheed people and did not make much secret of that, which probably ruffled some Lockheed feathers. McCartney admitted

> It was probably pretty cocky too, you know, but we were good. . . . I call it friendly competition, but we were dead serious about making sure that we would be better than [the Lockheed controllers] were. And what is better is meaning that you can handle the [supports] smoother. You had better command, knew what the equipment was doing and not doing. You knew the capabilities of the crews. We used to practice endless hours with the crews at the stations, and we could work problems faster.[29]

As far as McCartney was concerned, relative skills as a satellite operator had nothing to do with education. Everyone involved in the satellite reconnaissance business had a comparable engineering education. In McCartney's mind, the military officers's ability to think faster and maintain their composure under pressure made them better operators.[30]

Eventually, the three young captains became full-fledged test controllers and Lockheed scheduled them along with their own people. This small victory marked the beginning of the air force's transition to all-military space operations. McCartney and crew sat on-console, pulling shifts, equals with the Lockheed employees. Lewin confirmed McCartney's estimation of the air force relationship with the contractor. "We were equals with the Lockheed guys, [and we] worked side-by-side with them." No differences separated a Lockheed employee and an air force satellite test controller. They worked side by side without distinction. They all had a great deal of pride in what they did, and the Lockheed people made them part of the team very quickly.[31] Thinking back

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[29] Ibid.

[30] Ibid.

[31] Lewin interview by author.

on his days in the Air Force Satellite Control Facility, McCartney said no one had a feeling one way or another about moving satellite operations to uniformed personnel: "We just always thought it would happen, and took it for granted. We just believed that would happen. I mean, it was just a question of time. . . . I never questioned but that sooner or later it would transition to blue-suiters."[32] Col. Frederic Oder, head of the satellite program office in Los Angeles, had a transition to military in mind all along.[33]

The air force also grew increasingly convinced that it could handle operations and maintenance on its own, using officers to "fly" satellites and enlisted technicians in the same sorts of maintenance roles they performed in flying wings. A May 1962 manpower study submitted to Space Systems Division in Los Angeles suggested turning over communications at the Satellite Test Center to airmen. In fact, "blue-suiting" the entire satellite command and control operation could save the air force $400,000 annually.[34] After all, a technical sergeant (E-6) with ten years of service earned only $290 a month in 1963 (plus benefits, like commissary, base exchange, medical care, and so forth).[35] In 1958, a Philco employee at Annette, Alaska, earned $529 a month, plus free room and board, and Lockheed employees at Kodiak, Alaska, started at $400 a month, plus

[32] McCartney interview by author.

[33] Oder interview by author.

[34] *History of 6594 Aerospace Test Wing*, 1 Jan.-30 June 1962, 14.

[35] $3480/year plus a $110/month housing allowance, for a total of $4800/year (roughly equivalent to $28,000 2001 dollars). Source: "Monthly Basic Pay and Allowances table, effective 1 October 1963," http://www.dfas.mil/milpay, accessed 17 Oct. 2000.

benefits.[36] The air force had an obvious financial advantage in blue-suiting operations and maintenance, but the resulting lack of experience imposed long-term consequences on the Air Force Satellite Control Facility.

The lack of training material challenged newly-assigned airmen the most. Second Lieutenant Lou Adams joined the Air Force Satellite Control Facility in 1966, after graduation from Radar Maintenance Officer School at Keesler AFB, Mississippi. Because the air force did not have a space operations career field for officers or enlisted personnel, it sent them to the schools that most closely resembled the work they would do in the Air Force Satellite Control Facility. Assigned to the New Boston Tracking Station in New Hampshire as an Operations Controller in the control room, Adams almost immediately noticed the wide variety of people working there. In the Control Room contractors and officers of varied backgrounds, education and experiences, all did the same basic everyday jobs. In the work centers, contractors and enlisted personnel worked side by side. He had no formal training program or written material to study, so Adams faced no small challenge learning to become an Operations Controller. Each individual satellite program published and distributed a Technical Operations Order (TOO), which described the requirements, operations concepts, and technical aspects of the satellite(s) in a particular family, but nothing existed to put it all together for a trainee. Training essentially followed the hit-and-miss process of over-the-shoulder observations,

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[36] Howard Althouse, electronic mail to author, SUBJ: "Early Kodi," 18 Nov. 2000. Said Althouse: "Being single, no girlfriend, 25 years old, I said, 'I'll go!' The free room and board were the clinchers!" Said Bob Siptrott, "This included 3 great meals. An old movie once a night, access to our own bar. We paid for the booze. Decent rooms, clean sheets daily and blankets changed every other week" (Siptrott interview by author).

asking questions, and reading whatever available pertinent material.[37] Into the mid-1960s, the air force still largely did on-the-job training, despite whatever technical training the service provided beforehand.

Carl Malberg, who arrived in New Hampshire in 1962 as a second lieutenant fresh out of Ground Electronics Officer training, recalled that in the early days they even had enlisted members on the console in the control room as tracking controllers, and eventually as command controllers and even assistant operations controllers (AOCs). He did not recall an enlisted person ever sitting as an operations controller (OC), "but if they were certified as an AOC, they were certainly qualified to work as an OC." The various areas had enlisted technicians assigned, mostly instrumentation specialists, who pulled shifts right alongside the contractors. Once the person--officer or enlisted--certified in their primary job, they performed the primary duty under the watchful eye of a contractor. Before certification, the contractor performed the primary duty under the inquisitive eye of the blue-suiter.[38]

By late 1962, satellite crews at some sites were half contractor and half airmen.[39] At the Hawaii Tracking Station, nine officers and 39 enlisted worked with 126 Lockheed personnel, all of whom performed their assigned tasks "with competence."[40] Uniformed personnel did not have any more "competence" than contractors did. For example,

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[37] Louis Adams, electronic mail to author, SUBJ: "AFSCF History," 14 Dec. 2000.

[38] Carl Malberg, electronic mail to author, SUBJ: "BOSS," 15 July 2000.

[39] *History of the 6594 Aerospace Test Wing*, 1 July-31 Dec. 1962, Appendix 7, 2.

[40] Ibid., Appendix 5, 3.

Howie Althouse served at the New Boston Tracking Station as the area supervisor of the telemetry area in 1963-1964:

> I had 66 TechReps working for me, [and I was] responsible for 2 telemetry areas and 3 shifts (24 hr. support). [I also] had a dozen or so airmen assigned, [but I] couldn't count on them much as you never knew when they would be there to work a shift. Between having to go to Grenier Field, [New Hampshire] or Hanscom AFB[, Massachusetts, about an hour away] for medical, dental, records check, or whatever, they were unreliable for support. Anyhow, we [contractors] supported.[41]

These satellite command and control crews, a highly motivated group of contractors and military, cross-trained and certified in multiple positions. They worked with innovative, state-of-the-art technology, functioning as a team, regardless of employer. In Sunnyvale, the contractors and military "welded into an effective technical organization completely dedicated" to the Air Force Satellite Control Facility mission. Shift supervisors, uniformed or contractor, had full charge of all personnel, military or Lockheed, designated to work on their shifts. The shift supervisors, regardless of employer, "all professionals in engineering and science," exhibited "professional job performance."[42] At the tracking stations, a contractor regularly acted as the operations controller with an air force assistant on one support and then they often switched for the next satellite support. That way everyone stayed current in all procedures.

The air force did not have a "Satellite Operations" career field for officers or enlisted until the 1980s. The Air Force Satellite Control Facility had to derive capable operators from a number of different air force career fields, many already critically-staffed, difficult to fill, and difficult to retain. The problem only grew more critical as the

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[41] Howard Althouse, electronic mail to author, SUBJ: "BOSS," 12 Dec 2000.

[42] *History of the 6594 Aerospace Test Wing*, 1 Jan.-30 June 1964, Atch 1, 4, AFSPC/HO, Box 3-3-2.

United States expanded its role in Vietnam and as the aerospace industry expanded to meet the needs of the Cold War. Finally, the unique environment of the AFSCF meant a large on-the-job training investment with a small return on outlay because of low retention probability and low experience levels. It all added up to chronic personnel problems.

Another money and time-saver, the Multiple Satellite Augmentation Program, introduced new computers to some of the stations. At New Boston, the implementation of MSAP went as smoothly as anywhere in the Air Force Satellite Control Facility. Two CDC 160A computers replaced the older CDC 1604s and analog computers. One CDC 160A formatted tracking data and handled commanding; the other formatted telemetry for real-time relay to Sunnyvale on a higher data rate microwave link. These two computers interfaced with a CDC 160A at the Satellite Test Center called the "Bird Buffer," which moved the data to where it needed to go. MSAP also replaced the VERLORT antenna at New Boston (it later became the nucleus of the Guam Tracking Station). In its place, the station received a sixty-foot, three-axis hydraulic antenna and a second control room, becoming a dual-sided station capable of simultaneously supporting two satellites. MSAP, although good for satellites, hurt morale because staffing did not increase to meet the new workload. In fact, personnel numbers decreased as the station went from four shifts to three with only every third weekend off.[43]

Before long, an increasing workload justified an increased number of personnel. Despite the Multiple Satellite Augmentation Program installation, the remote tracking

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[43] Malberg, "NHS 1962-1966," 8.

stations believed their personnel requirements should remain high because the number of supported satellites rose with each launch success. New Boston complained in early 1963 about operating under strength twenty-four hours a day, seven days a week, creating "a fatigue and potential morale problem." New Boston supported just seventy-seven passes in June 1962 and a mere forty-six in July 1962, in comparison to their 1,399 passes in January to June 1963, an average of over 230 a month.[44] New Boston had a total assigned strength of twenty-nine officers, 315 enlisted personnel and 412 contractors; the three operations crews consisted of 54 percent military and 46 percent contractor.[45] MSAP clearly had an effect on numbers of satellite supports. Understaffing remained a serious issue because of the steadily increasing support load.

Problems in the air force personnel system also had an effect on staff. The major area of concern at New Boston soon became the "staggering military attritional losses without replacement [*sic*]." New Boston had reached four years of continuous operation in 1963. The air force normally rotated personnel on to their next duty station at three or four years of time at one base, but the contractor population seldom moved. From January through June 1963, the station suffered the loss of thirty-seven fully trained, highly skilled technicians

> compared to a replacement factor of five, low-ranking . . . technical school graduates. Contractor-wise, seventeen experienced Philco employees departed and nine new inputs were gained. A problem area has been losing qualified troops and gaining basic airmen. With contractor replacements, the situation has been more fortunate in that replacements are from Vandenberg AFB, Thule [Greenland] and Annette [Alaska, recently closed],

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[44] *History of the 6594th Test Wing (Satellite)*, 1 Jan.-30 June 1961, Appendix 5, 3.

[45] *History of the 6594th Aerospace Test Wing*, 1 Jan.-30 June 1963, 15-16, AFSPC/HO, Box 3-3-1.

> thus a reduction in transition training requirements. The salient feature of the manpower crux is a bare minimum of three crews and a steadily increasing workload [*sic*].[46]

Personnel problems worsened before improving, not just at New Boston, but everywhere.

An ordered reduction in contractor personnel accompanied the Multiple Satellite Augmentation Program upgrade. At New Boston, station prime contractor Philco planned an overall reduction of seventy personnel, almost half the total staff. Because the phase-out of old equipment served as the basis for the personnel reduction, the station became increasingly alarmed as it became apparent that the air force would not phase out the old equipment on schedule. The station commander contacted his headquarters, but received no response.[47]

Eventually the General Accounting Office stepped in and said that the government could contract for an end item, but that the contractors working in the AFSCF were actually performing illegal "personal services."[48] In response, the air force decided to staff the Vandenberg station with only military and to staff the other stations with only contractors. This compromise tested the feasibility of an all-blue-suit operation, provided a comparison for the contractor-operated stations, and preserved the illusion in the air force of a uniformed ability to command and control satellites. The air force sent selected military personnel from the other stations to staff Vandenberg. In reality, Vandenberg never achieved a truly all-blue-suit status. It always had a cadre of

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[46] Ibid., 9.

[47] Ibid., 2-3.

[48] United States Congress, House, *Decision of the Comptroller General of the United States Regarding Contractor Technical Service,* 89th Cong., 2d Sess., House Report 188 (Washington: Government Printing Office, 1965), 5.

technical advisors assigned to each work center to assist with training and to provide technical assistance as needed. Then, once Vandenberg became the only station where military performed satellite control and maintenance functions, the personnel problem became acute because no other stations could rotate personnel to California. Moreover, the air force personnel system, already unable to satisfy the personnel needs of the unique AFSCF, viewed the organization as an R&D outfit rather than an operational or warfighting unit. Many contractor technical advisors augmented the air force operations and maintenance teams because of turnover and chronically low experience levels. Once personnel issues became a nagging problem, the air force threw in the towel, transitioning Vandenberg to an all-contractor staff.[49]

Personnel problems remained a headache for the Air Force Satellite Control Facility leadership until well into the late 1960s. The air force constantly dealt with the conflicting desires of wanting to do operations with military technicians but not being able to because of a lack of trained personnel. With the increasing demands of the Vietnam War drawing away technical personnel, the military began to run out of enlisted technicians, making the goal of an air force that could provide satellite command and control using uniformed staff a harder one to meet. Filling in the gaps with either contractor personnel or more technology to eliminate personnel seemed to be the only

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[49] Louis Adams, electronic mail to author, SUBJ: "Re: AFSCF History," 12 Dec. 2000; W. Warren Pearce, telephone interview by author, tape recording, 12 Nov. 2000. In *The Social Cost of Maintaining a Military Labor Force*, RAND suggested that the social welfare cost of the draft was nearly $2.4 billion 1974 dollars. Overemployment and low wages encouraged the military to use more labor resources and less capital than that which was optimal, in effect doing jobs less efficiently than it could otherwise. (See: Richard V. L. Cooper, *The Social Cost of Maintaining a Military Labor Force* [Santa Monica, CA: RAND, R-1758/1-ARPA, 1975].)

solutions. As the personnel available to Air Research and Development Command shrank, the military and the contractors had no option but to work together to win the technological war. As the Air Force Satellite Control Facility overcame each reverse salient, it built momentum for the future.

The air force leadership wanted to establish a uniformed capability to perform all of the complex operations required for the command, control, and recovery of satellites, but by 1964 an acute shortage of uniformed personnel with the appropriate technical qualifications made it unlikely the air force could ever achieve an all-blue-suit operations and maintenance capability for space. By the end of the 1960s, the air force gave up on military space operations and maintenance, and fell back on the original plan, relying on contractors to perform the vital national service of satellite command and control.[50]

Operations Culture vs. R&D Culture

The approach to operations competing for influence within the Air Force Satellite Control Facility was another interesting aspect of the system's technological style. If the Air Force Satellite Control Facility's inventor-entrepreneurs invented anything, they invented a concept of operations that resisted standardization in favor of the flexibility necessary in a test environment. The air force tried to overcome the momentum induced by the R&D culture and the special relationship the AFSCF had with the NRO. Overcoming this concept of operations proved difficult. To normalize space operations,

[50] "Report on the Manpower History of the Air Force Satellite Control Facility, 31 Jan. 1959-6 Oct. 1967," in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1967, Atch 4, AFSPC/HO, Box 3-5-1, Folder JD67.

the air force tried to "operationalize" the AFSCF, trying to make satellite command and control more like flying standardized fighter or tanker aircraft than specialized test planes. The air force struggled while trying to standardize satellite command and control operations because no one really had any idea how to control a satellite in the first place.

The air force considered a lack of formal training acceptable because of the test nature of the space operations environment. Trying to learn and understand orbital mechanics challenged the newest space operators who learned without formal schools or textbooks for satellite hardware, orbital mechanics, or vehicle commanding. The satellite operators depended on Lockheed to help them with technical training such as understanding Agena commands and what the commands did. Lockheed built the Agena right across the street from the satellite operations area in Building 104, so the operators often went over there to see the equipment before it reached orbit. Life for a new satellite operator included constant study and an internal class. The operators went to meetings, got data, and would say "Hey, that's a good book on that," so, they, in a sense, "scavenged" their equipment and their libraries, figuring out what forms made the best sense.[51] CORONA's status as a test program let them take their time.

Then-Captain Mel Lewin had an uncanny ability to put an enormous amount of data on a single slide. He got the forms and the data and the tools that the new satellite operators needed--"crutches, really," said one former satellite operator--and they always carried a set of their own "cheat sheets" that helped prompt them. In addition, the Air Force Satellite Control Facility rehearsed an on-orbit operation almost every day, whether

[51] McCartney interview by author.

a vehicle orbited or not, by taking tapes from previous flights and playing back the data. The technician in the back of the control room tried to see if he could devise a problem that would fool the person trying to control the vehicle. General McCartney recalled that sitting on console as a satellite operator felt like "a pressure cooker thing, because in those early days that equipment was not very good to you. You . . . really had to think ahead, and you had to be able to . . . assess the situation, understand what was going on, think on your feet, figure out what to do, and do it. And, you didn't have time for other people to do any real prompting of you."[52] Never treating a rehearsal or a simulation like a game, the operators learned through the devious problems they threw at each other. Eventually, all the rehearsal time paid off "big time."[53] Before achieving a fully blue-suit status, one capable of standardized operations, the system had to have more formalized procedures.

The lack of formal procedures caused some problems in the CORONA program. In late January 1968, for example, on Mission 1045, CORONA Flight 123, the vehicle ran into some difficulties when the Field Test Force Director made an error calculating the number of commands required to go from the acquisition command position to the fade command position, in part because of abnormal telemetry from the vehicle. The problem occurred because the other operators did not verify his calculations; the operations planner and test controller simply initialed the master command sheet, assuming the Field Test Force Director had gotten it right. The incident prompted an

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[52] Ibid.

[53] Ibid.

investigation, and Col. Charles Murphy, the investigating officer, relieved the Field Test Force Director of his position and issued letters of reprimand to the individuals on duty that day who failed to verify the command calculations. Colonel Murphy also introduced a new procedure to prevent recurrence, making each member of the control team compute the number independently.[54]

In part, the air force stuck with the test culture because it functioned less rigidly than the culture of aircraft or missile operations. Before it separated itself entirely from the Air Force Satellite Control Facility, the weather satellite program had a five-person office, meaning they had no bureaucracy that had to be satisfied before they could move on a problem. Only the Director of the National Reconnaissance Office (DNRO) could say no to Col. Tom Haig, and DNRO usually said yes when Haig proposed something new for the weather satellite program. In addition, Haig achieved a high morale in the weather satellite program office by making the officers responsible for the program and then making their decisions stick. For example, Captain Dick Geer ran the booster part of the weather satellite operation. He figured out why the program lost so many small NASA-built Scout boosters. The first launch failed because the third stage blew up after a bad ignition. The second launch succeeded when they got the satellite into an orbit satisfactory enough for the weather data. The third and fourth launches again failed, but each occasion looked like something other than an ignition failure. Geer figured it out: the safety range officer shut down the transmitter illuminating the booster when it ran out of the range boundaries. When he turned off his transmitter, the automatic gain control

[54] MSG, Col. Charles Murphy, no subj., 2 Feb. 1968, NRO, 5/B/0065.

on the receiver in the booster went up to maximum and it picked up random emissions from broadcast stations in Los Angeles. Geer claimed Frank Sinatra's voice singing at his higher register triggered the destruct mechanism. More than likely the explosion occurred when a spurious signal from a radio broadcast in the area set off the destruct mechanism. In a sense, the air force destroyed its own boosters until Geer figured out that the range safety officer had to illuminate the receiver all the way into orbit. On Geer's suggestion, the range controllers changed their procedures, preventing further accidental Scout booster explosions. As Col. Haig put it, Geer "had to be pretty sharp to figure that one out."[55] The test culture, nonexistent in the operational air force, gave Geer the latitude to figure out the problem.

After it pulled out of the Air Force Satellite Control Facility, the weather satellite program achieved the first truly "operational" status of any space program. Weather satellites operated every day and required staffing the tracking stations and a control center on a continuous basis, in contrast to the intermittent staffing required for the CORONA vehicles. In 1962, SAC took over the operations for the weather satellite program, making it the air force's first operational satellite mission. For the next six years the "SAC-umsized" operators never missed a satellite support operation, including the time that a Nor'easter blew the inflated radome off the antenna at the station near Loring, Maine. The maintainers went outside in the inclement weather and held the edge of the receiver dish. The forty-foot dish vibrated wildly in the high winds. While it tracked the satellite for a weather data readout, the crew held the dish to keep it from

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[55] Haig, *Quest* interview, 56.

vibrating so that they could stay on the vehicle and get a clear signal. The operational, mission-oriented culture they learned in SAC pushed them to such an unusual effort, proving that the informal R&D culture was not the only method of operating a satellite command and control system.

For Colonel Haig, the whole experience with the all-blue-suit launch and operations crews also confirmed his opinion that the air force could run a satellite program much better than contractors could. The difference, in his mind, included focus, dedication, basic intelligence, and competence. Said Colonel Haig later, "My faith in blue-suiters is unbounded. There is no one outside [the Air Force] who is smarter than those who serve on the inside."[56] Captain Charlie Croft in the weather satellite program office found a couple of abandoned army Nike missile stations, one in Washington state and the other in Maine, about to become county parks, and latched onto them for two ground stations. The sites had old but serviceable wooden buildings. When he got permission from the Director of the National Reconnaissance Office, Colonel Haig went out and briefed Air Force Chief of Staff General Curtis LeMay and SAC boss General Power, and within a week crews at those two stations began repairing the buildings. "[B]y golly, by the time we got the [weather satellite program] equipment up there, they had 'Spic and Span'd' the buildings and grounds, and the morale was so high you just couldn't stop them. They were great guys."[57] Strategic Air Command interviewed and

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[56] Haig, comments during the Air Force Space and Missile Pioneers Roundtable, 21 Sept. 2000, Colorado Springs, Colo. This event was one of several surrounding the induction of Colonel Haig into the Air Force Space and Missile Hall of Fame.

[57] Haig, *Quest* interview, 55.

recruited good officers and enlisted technicians at the ground stations and control centers, telling these space pioneers, "You're the first military crew to run a space program. You are the basis. You're the foundation for the Air Force's mission in space." SAC drilled that fallacious belief into them from Commander-in-Chief General Thomas Power on down, but they believed it and performed that way. SAC required its strict form of checklist discipline and regular way of operations, and the weather satellite program went on to become one of the great success stories of the Air Force's space history.

The Strategic Air Command story in space operations makes a perfect counterpoint for this story of a large technological system because it was the exception, not the rule. Until the 1980s, the Air Force Satellite Control Facility remained in Air Force Systems Command, the air force major command responsible for research and development. The AFSCF remained an organization with a "make it up as you go" attitude, even as operations grew significantly more standardized.

The introduction of the Mission Control Center in the mid-1960s standardized satellite operations procedures more than any checklist-driven culture could have. With *Project Forecast* in 1964, the air force looked ahead in the same way Theodore von Kármán had made the service think about new roles, missions, and opportunities in *Toward New Horizons*. For this new project, uniformed engineers led the study's panels, not civilian scientists. Headed by Air Force Systems Command leader General Schriever, whom General Hap Arnold himself had profoundly influenced when they were stationed together in California before World War II, *Project Forecast* tried to take a long-range look at air force research and development in an attempt to predict the

changes that might occur in the next ten years.[58] Best known for its endorsement of the doomed Manned Orbiting Laboratory, the study included an examination of command and control and a specific look at the importance of command and control for space. The Mission Control Center concept of operations emerged in an air force attempt to redefine its role as the operator of the nation's military satellites.

Brig. Gen. Jewell C. Maxwell chaired the Space Support Panel. Annex E of Volume III, Space Command and Control, laid out a roadmap for developing future space test facilities and operational command and control networks. The logical path, the Maxwell panel argued, meant developing space operations the same way that airmen had developed air operations for a generation--using the concept of centralized control and decentralized execution. To work as efficiently as it worked for airplanes, the concept first required decentralized mission control centers. In the new concept of space operations, mission control center commanders had complete operational control of their satellites, just as pilots had complete operational control over their aircraft. Each mission control center had the ability to receive, analyze, and process payload data, generate their own orbital ephemeris, and issue commands. The Maxwell panel conceived of mission control centers as decentralized elements in the space mission, "mission-oriented control centers" capable of performing all the unique or peculiar functions necessary to perform the satellite's mission, often reconnaissance of the Soviet Bloc. As independent units plugging into the common-user Air Force Satellite Control Facility, mission control

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[58] Bernard C. Nalty, ed., *1950-1997*, vol. 2 of *Winged Shield, Winged Sword: A History of the United States Air Force* (Washington: Air Force History and Museums Program, 1997), 357; Spires, *Beyond Horizons*, 131; Schriever interview by author.

centers could be added to or deleted from the satellite command and control system without major disruption.[59] The concept took a step towards an operational space corps, one separate from the flying air force.

The mission control center concept also increased the independence of the individual satellite programs. During a mission, satellite operators in a mission control center exercised control over the ground facilities of the Air Force Satellite Control Facility only for the period allotted by the schedule. After the mission time elapsed, another mission control center that had prearranged for the time could step in and take over control of the resources of the AFSCF. Using the analogy of the air traffic control system, the report stressed that supporting satellites could be just as simple as flying airplanes and scheduling commercial airliners. The mission control center concept also provided added security and isolation for the various satellite programs.[60] With satellite operations and planning contained in a single unit behind a single entry door, satellite programs increased the level of secrecy of their missions, a further step in the direction of independence for air force space operators.

Aerospace Corporation took the idea of mission control centers and included it in its suggestions for expanding the Sunnyvale operation. In the Aerospace Corporation concept, all of the elements of satellite program control and satellite program operation occupied the same area, rather than remaining separated as in the older configuration of

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[59] Brig. Gen. Jewell C. Maxwell, Chairman, Space Support Panel, Annex E of Volume III, Space Command and Control, *Project Forecast*, January 1964, E-2-E-3, AFHRA, 168.7171-218.

[60] "History of the Test Control Branch," in *History of 6594th Aerospace Test Wing*, 1 Jan.-30 June 1965, AFSPC/HO, Box 3-3-2.

the Satellite Test Center. The test controller, now called a "mission commander," worked with key personnel in a single, secure, multiroom complex, keeping track of data as a computer displayed it on TV screens in a centralized operations room. The functions performed in the complex included orbit planning, data analysis, payload analysis, command generation, and direction of the tracking station assigned for support of the satellite. The new mission control console had seven television monitors, on which the operators could select any one of twenty separate telemetry channels, all coming into the complex in real-time thanks to the Space-Ground Link Subsystem modification. The console also had two remote control units for 35 mm projectors, secure and nonsecure telephones, and time-display units. In Aerospace Corporation's opinion, the mission control center arrangement more effectively employed the "highly trained engineer and technician personnel" assigned to the Satellite Test Center.[61]

The air force used the mission control center concept to justify an increase in personnel for the Sunnyvale operation. The air force's 1966 decision to operate the Manned Orbiting Laboratory in Sunnyvale rather than NASA's Manned Spaceflight Center in Houston prompted a major expansion of the Satellite Test Center, including an additional $1.2 million building with twelve new mission control centers.[62] The cost soon ballooned when the air force added four floors to the operations building and bought land for it from Lockheed, boosting the price to $8.2 million. When Congress found out

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[61] "Justification of Increased Manpower Requirements, FY 1968-1970," in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1965, AFSPC/HO, Box 3-3-2, Folder JD65.

[62] Gerald T. Cantwell, *The Air Force in Space, Fiscal Year 1966* (Washington: USAF Historical Division Liaison Office, 1968), 67, AFSPC/HO.

the air force planned to buy the land from Lockheed for $49,000 an acre, they balked at including it in the Military Construction Program for 1967.[63] Congress eventually relented and approved the new windowless blue building before the AFSCF outgrew its accommodations. Today they simply call it "The Blue Cube."

Each mission control center now had its own complete operations team, whereas the satellite programs earlier had shared some personnel. The mission control centers took personnel from existing functional areas of the Satellite Test Center, introducing considerable duplication because each mission control center operated just one family of similar satellites. In mid-1965, the central control center in Sunnyvale included 123 officers, 208 airmen, eight civilians and 405 contractors, totaling 744 personnel. The air force believed that an expansion of the Sunnyvale operations to twelve mission control complexes, even before Manned Orbiting Laboratory requirements, needed an additional 429 personnel authorizations, including 171 officers, 252 airmen, and 6 civilians, plus 230 contractor spaces, a total of 659 new personnel for Sunnyvale.[64] As justification for the huge increase in staff, the air force offered a brief history of satellite operations. From 1959, when the service activated the 6594th Test Wing operation at Sunnyvale, until 1961, staff increased as rapidly as the number of satellites the test center supported, about 60 percent. With the longer life of satellites and the increasing number of satellites in space, on-orbit operations stood at 6,500 satellite support operations in 1963; planners

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[63] Gerald T. Cantwell, *The Air Force in Space, Fiscal Year 1967*, Part 1 (Washington: USAF Historical Division Liaison Office, 1968), 61, AFSPC/HO.

[64] *History of the 6594th Aerospace Test Wing*, 1 Jan.-30 June 1965; "Justification of Increased Manpower Requirements, FY 1968-1970," in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1965, AFSPC/HO, Box 3-3-2, Folder JD65.

expected satellite support operations to almost triple to 18,800 by 1965, without an increase in personnel. The STC absorbed the increased workload "by more efficient equipment, better organization, streamlined procedures, and excessive overtime by both military and contractor personnel."[65] In short, the Sunnyvale operation nearly doubled in size because of the new Manned Orbiting Laboratory mission and the new mission control center concept.

Blue-suiting air force space operations remained a justification for increasing personnel. The air force insisted it needed to maintain a military capability at the Satellite Test Center: "[W]e *highly desire* the authorization of these 429 military spaces, if the Air Force is to retain a significant capability in the command and control of satellite operations."[66] The request suggested that the air force could reduce military requirements by replacing those positions "with higher cost contractor personnel." The Air Force Satellite Control Facility did not want to replace military with contractors "since it would reduce military control of space operations."[67] When Air Force Systems Command sent its authorization message, the AFSCF received 466 additional personnel authorizations, only about two-thirds of its request.[68] The AFSCF did not use contractors

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[65] "Justification of Increased Manpower Requirements, FY 1968-1970," in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1965.

[66] Ibid. Emphasis in the original.

[67] Ibid.

[68] MSG, Air Force Systems Command, SUBJ: "Manpower Authorizations for the AF Satellite Control Facility," to Space Systems Division, 7 Jan. 1966, in *History of the Air Force Satellite Control Facility*, 1 Jan.-30 June 1966, AFSPC/HO, Box 3-5-1, Folder JJ66.

to make up the difference, choosing to implement the mission control center idea, anyway.

In May 1966, crews in the first mission control center conducted a satellite support with the Hawaii Tracking Station using the new concept. The mission control center concept thereafter became the standard for air force satellite command and control operations. Every air force satellite operations squadron operates on this concept. In late 1966, several satellite programs moved their operations into mission control complexes. Satellite programs using the mission control center concept found "the complex to be very satisfactory." By the end of 1966, while operations continued in the Central Control Room, the four mission control centers gave the AFSCF the capability to support ten different satellite programs at once.[69] Satellite operations increased dramatically in the period that followed. In the first six months of 1966, the Air Force Satellite Control Facility supported sixty-four vehicles during 3,776 supports, an increase of fifty-six percent over 1965.[70] Operations became standardized like any operational air force flying unit.

Later, even more standardized procedures came into the AFSCF, from air force regulations to inspection directives. In 1968, the evaluators in the AFSCF's Standardization/Evaluation Branch concerned themselves with the quality of satellites support. The evaluators uncovered a tendency in the control rooms to lose sight of the

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[69] "Historical Report," Test Control Branch, n.d., in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1966, AFSPC/HO, Box 3-3-2, Folder JD66.

[70] "Historical Report," Test Control Branch, 21 July 1966, in *History of the Air Force Satellite Control Facility*, 1 Jan.-30 June 1966, AFSPC/HO, Box 3-5-1, Folder JJ66.

mission during long-duration satellite support operations of high altitude vehicles. In other instances, inadequate staffing, because of high personnel turnover at some stations, did not ensure optimum support or the ability to cope with possible contingencies. Thule, for example, experienced a 38 percent turnover of contractor technical personnel during the first six months of 1965.[71] At other sites, operators did not accomplish their training on new equipment like the Space-Ground Link Subsystem; they often supported on-orbit vehicles without formal training. Evaluators also found that the condition of the command transmitter equipment generally scored "substandard." Maintenance personnel assigned to this equipment, usually new AFSCF personnel, did not receive adequate training in how to maintain the equipment properly. As command transmitter maintainers became qualified, they moved on to more complex equipment such as the Space-Ground Link Subsystem, adding to the shortage of experienced personnel. Critically, evaluators found FR-1600 telemetry recorders in bad operating condition or totally inoperable because of poor training, no performance of periodic maintenance, or stations lacking the maintenance equipment for these important backup tools. Evaluators found training deficiencies occurred during the sudden changeover from military to contractors at most stations, which caused a sudden and heavy satellite support workload. By the end of 1968, Lockheed and Philco had many of the problems under control.[72]

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[71] "Historical Report," Operating Location 5 [Thule Tracking Station], in *History of the 6594th Aerospace Test Wing*, 1 Jan - 30 Jun 1965, AFSPC/HO, Box 3-3-2. Thule's turnover still remains higher than any other tracking station in the network.

[72] "AFSCF Operations Capability Evaluation Summary for Calendar Year 1968," in *Air Force Satellite Control Facility History*, 1 July-31 Dec. 1968, Atch 1, 1-13, AFSPC/HO, Box 3-4-1, Folder JD68.

In sum, the technological style of the R&D culture of Air Force Systems Command built momentum in the air force system of satellite command and control. To normalize space operations, and to make a stronger case for it as the nation's provider of military satellite command and control, the air force tried to "operationalize" the Air Force Satellite Control Facility, to make satellite command and control more like flying aircraft than specialized individual satellites. Introduction of the mission control center concept attempted to overcome institutional momentum, but if anything, it simply built another kind of resistance by further isolating the satellite programs from each other.

Summary

By the end of the 1960s, the air force had given up on uniformed operations and maintenance, and fallen back on the original personnel plan, having contractors perform the vital national service of satellite command and control. The engineers inside and outside the air force, whether contractors, civilians, or military, built the AFSCF because they had unbounded faith in each other that they could get the job done and that they had the technology to make satellite command and control work. And in the middle of the Cold War, they also had unbounded faith in their country, knowing that the network they built supported the national space program, an international source of prestige for the United States. Those with special access worked with extra diligence, knowing that the Air Force Satellite Control Facility supported the National Reconnaissance Program, considered essential to the country's security in the dangerous days of the Cold War.

Technological systems, even after prolonged growth and consolidation, do not become autonomous; they acquire a technical and organizational mass, giving the system a sort of "momentum." A high level of momentum often suggests to outsiders a system's autonomy; mature systems like the AFSCF, however, only appear autonomous, a concept corresponding to inertia. In his classic work on the philosophy of technology, Langdon Winner warned against the assumption that technology can escape human control. Winner examined the notion that somehow technology can spin out of control and follow a course independent of human direction, using "autonomous technology" as a general label for his observations that people believe that human agency somehow no longer controls technology. Writers like Jacques Ellul, John Kenneth Galbraith, and Bruno Bettelheim, adopted the idea of autonomous technology because so many of the most fundamental expectations about the progressive march of technology no longer held water as humans seemed to have lost control of technology. Winner characterized as a myth the notion that technical forms are merely neutral, arguing that this myth no longer deserved any respect.[73] This particular technological system for satellite command and control had a mass of organizational and technical components; it possessed direction, or goals; and it displayed a rate of growth suggesting velocity, but it did not develop autonomously. It developed through the involvement of human beings.

In the case of the Air Force Satellite Control Facility, an extraordinary player in the background continued to pulled strings. As the AFSCF grew in capability and importance for the overall national space effort, a struggle inside the air force ensued

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[73] See Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge: MIT Press, 1977), esp. 14-25, 325-33.

over control of the military satellite command and control system, requiring the AFSCF to acquire a sponsor. This patron turned out to be the National Reconnaissance Office, which was also looking after its own parochial interests.

CHAPTER 6

"THE PRESSURE COOKER": OVERCOMING MOMENTUM

> You can't run an operation given a black [covert] status and not bring the operators in because then they don't know what the hell's going on. . . .[1]
>
> -- General B. A. Schriever, USAF, Retired
> Former Commander, Air Force Systems Command

> If you're not measuring, you're not managing.[2]
>
> -- Brigadier General William G. King, Jr., USAF, Retired
> Former Commander, Air Force Satellite Control Facility

When Brig. Gen. William G. King, Jr., became the commander of the Air Force Satellite Control Facility in September 1966, he introduced a scoring system for the remote tracking stations to keep records on station performance in supporting the National Reconnaissance Program. The senior members of his staff resisted the idea as "too complicated" and possibly even damaging to morale, but King implemented the system over their objections. King ordered the scores sent by teletype to all the stations so they could compare themselves to each other. In King's mind, the satellite programs using the Air Force Satellite Control Facility needed to know about the stations and

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[1] Schriever interview by author.

[2] King interview by author.

scoring them gathered performance information. Showing the stations their weaknesses also helped them improve their operations.[3]

Differences of opinion notwithstanding, everyone on King's staff and at the tracking stations scored the satellite support operations professionally. Formally known as the Performance Management Evaluation System, the largely subjective scoring program gave the Air Force Satellite Control Facility commander a monthly operational performance and discrepancy summary from the stations. Field Test Force Directors, the satellite engineers in Sunnyvale from the satellite system program offices, collected information on each satellite support operation, including a complete analysis of discrepancies that occurred during the prepass, pass, or postpass phases of a satellite support operation.

Unfortunately, General King's adjutant created a mess when the first set of scores went out to the stations. In those days, the air force classified as confidential associating the call sign of a remote tracking station and its military designator; for example, saying POGO and Operating Location 5, or Thule Air Base, Greenland, was classified Confidential. King's adjutant did not have a security clearance, so did not know which call signs went with which station, resulting in guesses that reversed some of the scores. COOK, the adjutant suspected, went with New Boston because it frequently won the award for the best dining hall in the air force; BOSS went with Vandenberg because the station could command satellites on the pad to verify everything before launch. Vandenberg actually scored the highest and New Hampshire the lowest but the official

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[3] *History of the Air Force Satellite Control Facility*, 1 Jan.-30 June 1968, Atch 12, Vandenberg Tracking Station, 39, AFSPC/HO, Box 3-4-1, Folder JJ68.

scores went out by teletype with Vandenberg as the worst station and New Hampshire as the best.[4]

When General King got back from one of his frequent trips to Washington, Col. Jerry Flicek, the Vandenberg Tracking Station commander, was waiting in the outer office. Flicek wanted to talk about the scoring message, but King tried to put him off. Flicek said, "We're not that bad," but King brushed him off with "I know, you're a good station, but I really have to go see my boss now." Flicek left and went back to the real COOK, Vandenberg AFB, the former Cooke AFB. When King came to work the next morning, he recalled, "somebody had put the biggest goddammed rooster you have ever seen in my office and closed the door. . . . What he did to that office, you won't believe it. I know damn well it must have been Jerry, telling me I was 'chicken.'"[5] Over many objections, the scoring system stayed. Today it helps the air force determine part of the award fee the satellite control network contractor earns.

Historians of technology acknowledge that system builders strive to increase the size of the system under their control, and this certainly was the case with the AFSCF. The Air Force Satellite Control Facility grew from a small, single-user, regional network of satellite command and control stations to an enormous, multiuser, worldwide system. Manager-entrepreneurs took over the AFSCF, gradually displacing the (pseudo-) inventor as the responding agent for the problems and needs of the network. As it grew, the

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[4] King interview by author. King recalled often thinking "Thank God for Thule," because New Hampshire often did not get the commands to the vehicle on a northbound orbit.

[5] Ibid.

AFSCF built a momentum that it used to keep out other satellite programs, beginning with the weather satellite program in the early 1960s.[6] Chapter 4 presented evidence of this danger in the conflict between Lockheed and the weather satellite program, as well as in the challenges that the network overcame using technology. The large mass building up in the AFSCF arose from the corporate and military organizations committed to it. Engineers, managers, technicians, civil servants, and politicians all had vested interests in the growth and durability of the AFSCF. This should grow clearer in this chapter in an examination of the development of the Space-Ground Link Subsystem (SGLS) and in a look at the organizations that tried to claim control over the AFSCF.[7]

Managers tried to overcome technological momentum by introducing the Space-Ground Link Subsystem and making the AFSCF important for every satellite program in the department of defense and valuable for some NASA programs as well. At the same time, SGLS helped the AFSCF overcome the momentum building up in the large numbers of personnel still required to operate the Multiple Satellite Augmentation Program system by reducing their numbers. SGLS, conceived of in 1962 but not introduced into the air force satellite command and control system until the late 1960s, made the AFSCF a common-user network, with the ability to serve every satellite program in development.

The concept of technological style introduced in the last chapter also rebuts the claim that technology is applied science, pure and simple. Technology is not only skills

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[6] Hughes, "Evolution of Large Systems," 64-66.

[7] Ibid., 76-78.

used to develop tools but also a system of knowledge upon which those techniques draw. Technology is the designing of means usually to achieve a social end, be it irrigation canals to feed thousands or, in this case, satellite command and control to support national defense. Therefore, engineering in this management-by-committee context is the process of social engineering.[8] Furthermore, a technological innovation like SGLS also involved managerial innovation because the air force satellite command and control system inextricably connected technology and management. Keeping the Air Force Satellite Control Facility as part of the engineering and testing community controlled not just the technological development of air force satellite command and control, but also controlled the management of the system itself.

The Air Force Satellite Control Facility's institutional and technological momentum proved difficult for manager-entrepreneurs to overcome. For example, the manager-entrepreneurs who ran the AFSCF and the primary customers who justified its existence--the national reconnaissance community--built momentum into the system. The Space-Ground Link Subsystem served both parties, advancing satellite command and control technology while enabling the development of even more sophisticated satellites. The AFSCF prospered in its special relationship with the National Reconnaissance Office as the system supported its patron, often at the cost of supporting other important national space priorities.

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[8] Ibid., 68-69; Merritt Roe Smith, ed., *Military Enterprise and Technological Change: Perspectives on the American Experience* (Cambridge: MIT Press, 1985), 10-17; Hughes, "Emerging Themes in the History of Technology," 698.

One must not ignore technological momentum's compelling force when exploring the development of large technological systems. The commitment of the engineers and managers to the AFSCF, and of the corporations heavily invested in it, Lockheed and Philco, contributed to the momentum of the network. By the late 1960s, the air force system of satellite command and control, a vast technological (but nevertheless not autonomous) system, had achieved a large amount of momentum.[9]

Space-Ground Link Subsystem (SGLS)

In the military system of satellite command and control, technological momentum manifested itself in the development of the Space-Ground Link Subsystem. While trying to expand into the realm of NASA support, the Air Force Satellite Control Facility remained in its place as the servant of the National Reconnaissance Office, even though it alone provided satellite command and control capabilities for the Department of Defense. The manager-entrepreneurs required SGLS to advance the AFSCF's capabilities well into the 1970s. They created not only a more capable system, especially as reconnaissance satellites increased in complexity and capability, but also made the AFSCF compatible with NASA's increasing fleet of space vehicles.

Satellite systems development required the integration of payload, booster, satellite vehicle, satellite control, and recovery subsystems. Their operational effectiveness and capability depended on the integration of the various subsystems and technical trade-offs between them. This process of compromise continued throughout the

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[9] Hughes, "Technological Momentum in History," 131.

research and development program, as systems engineering contractors determined each subsystem's own particular set of requirements and constraints. As with all the subsystems, the command and control subsystem had constantly changing constraints, including political limitations and limitations imposed because of the location of tracking stations, rapid technical advances in the security of communications links, or trade-offs between flight test performance and mission requirements. Trying to simplify as much as possible, while keeping the system as flexible as possible, constantly challenged the network engineers.[10]

In 1962, the Aerospace Corporation's Satellite Control Office and the air force's Satellite Systems Office had suggested a standardized command and control system to support the multiple satellite environment expected in the period after 1965. The new subsystem, called the Space-Ground Link Subsystem, integrated the separate tracking, telemetry, and commanding subsystems into a single subsystem, using a single, self-tracking ground antenna and compatible vehicle equipment on-board the satellite. Two separate systems handled those tasks in the first two AFSCF designs. The new design provided flexible communications channels between the ground and the vehicle, variable enough to satisfy a larger variety of satellite program requirements in command rate, telemetry rate, and tracking accuracy, by using a building block concept of modular equipment for satellites. The program office planned that SGLS would transmit ground to space in the 1.7 to 1.85 gigahertz frequency range, and to receive at 2.2 to 2.4 GHz.

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[10] Capt. Malcolm McMullen, Engineering Division, Space Vehicle Office, SUBJ: "Historical Report, 1 Jul 1962-31 Dec 1962," to Col. Appold, 22 Jan. 1963, *Space and Missile Systems Organization Historical Report*, 1 July 1962-31 Dec. 1962, AFSPC/HO, Box 3-3-1.

(NASA claimed the 2.2 to 2.3 GHz part of the frequency spectrum for their own use, but the United States government's Interdepartmental Radio Advisory committee, which made all radio frequency assignments to government agencies, gave the air force the complete spectrum for SGLS.) In addition, the new system included encryption and decryption devices for both ground-to-space and space-to-ground communications, adding a layer of security and reducing the threat of the Russian trawlers.[11] The new communications system simplified matters while making air force satellite command and control much more flexible and secure.

SGLS furnished the AFSCF with a common communications link by unifying telemetry, tracking, and commanding into a single system. The new technology provided voice, analog, and digital command services over a ground-to-space communication link, and voice and telemetry over a space-to-ground link. Simultaneously the system measured range, range-rate, and position of the spacecraft with respect to the tracking station, and did it all using only one antenna, thereby saving on maintenance costs and personnel. By multiplexing the command and tracking data onto a single uplink, and by multiplexing the tracking and telemetry data onto a single downlink, SGLS technology achieved much higher data rates. Some significant SGLS features included spacecraft equipment designed to meet the requirements of a variety of different space programs and data rates, and semiautomatic configuration control and test facilities to minimize operations and "maintenance personnel requirements." In addition, the requirements for

[11] Captain Schorsch, Systems Engineering Division, SUBJ: "Historical Report, 1 Jul 1963-31 Dec 1963," to SSEH, 30 Jan. 1964, *Space and Missile Systems Organization Historical Report*, 1 July 1963-31 Dec. 1963, AFSPC/HO, Box 3-3-1.

SGLS included the ability to reconfigure the ground station for another satellite support operation, the so-called "turn-around time," within five minutes, a significant advance over the hours it sometimes took to change from one satellite configuration to another.[12] Not only simpler, the new subsystem also saved personnel costs and satellite development time by standardizing all spacecraft communications equipment.

The air force went with a tried-and-true partner for development of the new communications system. In March 1963, the air force awarded TRW's Space Technology Laboratories a contract to define a detailed system configuration capable of meeting the anticipated needs of the air force well into the 1970s. STL suggested that the system meet the needs of a wide variety of air force satellite programs while remaining compatible with NASA's unified S-band communication system. STL also suggested that the new system be capable of further growth and expansion, while simultaneously eliminating the multiple-satellite problems that had plagued the Air Force Satellite Control Facility in the past.[13] In November 1964, the air force gave STL permission to proceed with the design and fabrication of two demonstration ground stations and eight sets of satellite equipment for four satellite flight tests to prove the system (each spaceflight had one redundant on-board system). The contractor delivered the Space-Ground Link Subsystem demonstration ground station to Vandenberg in October 1965,

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[12] P. Marshall Fitzgerald and Jackson Witherspoon, Philco-Ford Corp., *Space-Ground Link Subsystem Ground Station System Analysis Summary Report*, Vol I, "System Design Analysis," 15 Nov. 1968, v, 1-1, DTIC, AD853122; P. Marshall Fitzgerald and Jackson Witherspoon, Philco-Ford Corp., *General Specification for Performance and Design Requirements for the Space-Ground Link Subsystem Ground Station*, 12 Feb. 1969, para. 3.1.1.1, DTIC, AD853946.

[13] STL [Space Technology Laboratories], *Final Design report: Space-Ground Link Subsystem*, vol. 1, 1 Feb. 1967, 1-2, 1-3, DTIC, AD813154.

where they planned to perform the flight demonstrations. Shortly after the air force and STL signed the contract, an unidentified "potential user" asked for faster implementation of the basic SGLS system. At about the same time, the defense department stated its intention to abandon the Very High Frequency band of the radio spectrum for space operations by the end of 1969, so the AFSCF pushed up SGLS implementation. STL accelerated its schedule to meet the demands of the "potential user," completing the demonstration stations at Vandenberg and Thule by late February 1966.[14]

Installation engineers ran into difficulties in the design of the digital telemetry multiplexer for the satellite portion of SGLS. Their problems resulted in a cost overrun on the contract of well over $4 million. The air force approved the extra funds, pushing the fiscal year 1966 SGLS budget into a 17 percent overrun.[15] Despite the problems, in October and November 1966, the air force conducted two orbital SGLS tests with such a high degree of success that the satellite control program office in Los Angeles cancelled the remaining two tests. The two test ground stations, Vandenberg and Thule, transferred data to Sunnyvale for processing and display, thrilling satellite operators who could now monitor satellites in real-time. The cancellation of the last two flights of the test program

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[14] Gerald T. Cantwell, *The Air Force in Space, Fiscal Year 1966* (Washington: USAF Historical Division Liaison Office, 1968), 67-68, AFSPC/HO.

[15] Lt. Col. Robert S. Redpath, Chief, Equipment Development Branch, Development Engineering Office, SUBJ: "SSOND-2 History, 1 July 1965 - 31 Dec 1965," 26 Jan. 1966, 3; Major Henry L. Steven, Jr., Chief, Budgeting and Funding Office, SUBJ: "Historical Report 1 July 1965-31 Dec 1965," in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1965; Capt Sadovsky, SUBJ: "SSOND History, 1 July 1966-31 Dec 1966," 22 Dec. 1966, 8, in *History of the Air Force Satellite Control Facility*, 1 July-31 Dec. 1966, AFSPC/HO, Box 3-3-2, Folder JD66.

saved the air force $1.5 million and accelerated the system's operational capability.[16] The Air Force Deputy Chief of Staff for Research and Development ordered installation of the new equipment at all the AFSCF ground stations by the end of 1969.[17]

The air force began shipping equipment to the stations as fast as possible, which meant dealing with more problems. The testing for New Boston's SGLS equipment at the Developmental Test Facility in California finished on 27 January 1968 and Philco loaded the gear onto trucks. On the way to New Hampshire in February, the first of two cargo trucks had an accident, which damaged the signal switching facility, two magnetic tape recorders, and the ten-kilowatt transmitter, a piece of equipment worth well over $20,000. Philco shipped the equipment back to Palo Alto immediately, sending the replacements the same day. To take the SGLS equipment to Kodiak, the air force arranged for the freighter *City of Alma,* but because of a lack of crew, the ship did not leave San Francisco harbor. Lt. Col. Philip Porter and Capt. F. Boyle arranged to have the ship off-loaded and the equipment airlifted to Kodiak from nearby Travis AFB. Other complications arose when movers dropped the 10 KW radio frequency unit in Hawaii. The damage totaled more than $20,000 on the RF unit alone, but total damages

[16] Capt. Sadovsky, SUBJ: "SSOND History, 1 July 1966 - 31 Dec 1966," 22 Dec. 1966, 8-10, AFSPC/HO, Box 3-3-2, Folder JD66; Gerald T. Cantwell, *The Air Force in Space, Fiscal Year 1967*, Part I (Washington: USAF Historical Division Liaison Office, 1969), 59-60, AFSPC/HO.

[17] STL, *Final Design Report: Space-Ground Link Subsystem*, vol. 1, 1 Feb. 1967, iii-v, DTIC, AD813154. Then, almost as soon as they had successfully demonstrated SGLS's capability, AFSCF engineers began planning for the next generation, called the Advanced Space-Ground Link Subsystem, which would extend the data rate to 20 megabits per second, especially important for satellites at geosynchronous altitudes. The air force estimated the cost of the new program at $3.4 million over nineteen months.

during the rush to get SGLS to the stations exceeded $110,000.[18] Given the high-priority nature of the new communications system, the air force considered the losses acceptable. When the SGLS equipment finally arrived, Philco technicians quickly installed it. Testing at New Boston began on 18 March 1968, and finished on 15 April, with the air force taking possession of the equipment almost right away. At New Boston, the contractors offered eight training courses on operating and maintaining the new SGLS equipment. It graduated 137 students, mostly personnel who had been at the station for a while and who would operate the new SGLS equipment.[19]

A major evolutionary step for manager-entrepreneurs and the National Reconnaissance Program's capabilities, the SGLS implementation in the Air Force Satellite Control Facility took a lot of the decision-making out of the hands of the tracking stations and centralized it in the Sunnyvale operations center. The antennas at the tracking stations now acted only as conduits, passing data to or from the main control center in California, losing their ability to make decisions on their own about satellite missions. After SGLS, the AFSCF made no other major technological upgrades until the advent of the Automated Remote Tracking System in the 1980s, a system that took

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[18] *History of the Air Force Satellite Control Facility*, 1 Jan.-30 June 1968, Atch 5, p. 2; Atch 11, 2, AFSPC/HO, Box 3-4-1, Folder JJ68; *History of the Air Force Satellite Control Facility*, 1 July-31 Dec 1968, Data Hardware Branch, 2, AFSPC/HO, Box 3-4-1, Folder JD68. In 1969, the train carrying the radome panels for Vandenberg's antennas derailed near Buffalo, NY, causing a one-month delay in radome construction and forcing double-shifts for the personnel constructing them (Lt. Col. Daniel S. Barnes, Chief, Equipment Development Branch, Directorate for Development, "Historical Report," *Space and Missile Systems Organization History*, 1 Jan.-31 July 1969, 6, AFSPC/HO, Box 3-3-1, Folder JJ69).

[19] *History of the Air Force Satellite Control Facility*, 1 Jan-30 June 1968, Atch 5, p. 2; Atch 11, 2, AFSPC/HO, Box 3-4-1, Folder JD68.

advantage of the microcomputer revolution to scale back personnel at the tracking stations. SGLS technology successfully expanded the capability of the Air Force Satellite Control Facility, providing better service to its customers, the NRO among the most important. So far, we have seen the National Reconnaissance Office's influences on the development of the AFSCF. At this point, therefore, we should discuss the AFSCF's organizational momentum.

The NRO's Influence on Organizational Momentum

Technological challenges are certainly important, but large technological systems also face organizational challenges. General Schriever assumed that "increased scientific and engineering competence" would not speed up the rate of technical progress unless the air force learned to administer its resources "more wisely and efficiently," which it tried to do with the introduction of SGLS.[20] To get the stations set up as quickly as they did and to get them operational supporting CORONA and the programs that quickly followed remains a credit to the leadership in Los Angeles. As General King added later, the success of air force satellite command and control had as much to do with the leadership as it did with the money flowing in from the CIA.[21]

From the beginning, the Air Force Satellite Control Facility had a special relationship with the Central Intelligence Agency, one beginning with the CORONA program but evolving after the creation of the National Reconnaissance Office. President

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[20] "Air Force Systems Command," *Air Force and Space Digest* (Sept. 1962): 165.

[21] King interview by author.

Eisenhower's approval for the reconnaissance satellite program forced the CIA and the Advanced Research Projects Agency to provide all funding for reconnaissance satellite research, development, and procurement, while General Schriever's Air Force Ballistic Missile Division in Los Angeles acted as the executive agent for the program, running it day-to-day in an air force weapon system program office. President Eisenhower wanted the CIA to have complete and exclusive control of all the intelligence phases of the reconnaissance satellite operation, but left the air force to manage the technical aspects of the program's development. ARPA exercised general supervision over the development of the vehicle, but AFBMD handled the details, especially the provision of necessary ground facilities. The CIA participated by supervising the development of the actual reconnaissance equipment, and had responsibility for its covert procurement.[22] In fact, the relationship perpetuated a similar one the CIA and air force had during the development of the U-2 reconnaissance airplane, including some of the same people. As in the U-2 program, Lockheed served as prime contractor. Only a handful of people knew anything about the true nature of the satellite program as a reconnaissance vehicle.[23]

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[22] MEMO, Richard Bissell, CIA, to Maj. Gen. Jacob E. Smart, Asst Vice C/S, USAF, SUBJ: "Distribution of Responsibilities for CORONA," 25 Nov. 1958, NRO, 1/A/0008.

[23] MEMO for the Record, Gen. A. J. Goodpaster, 21 April 1958 NRO, 2/A/0043; MEMO of Conference with the President [on] 7 Feb 1958, Gen. A. J. Goodpaster, 10 Feb. 1958, NRO, 2/A/0040. Present at the conference besides Eisenhower and Goodpaster were Dr. James Killian, the president's science advisor, and Edwin "Din" Land, president of Polaroid and responsible for the development of the CORONA camera.

Despite the president's preferences for security, the reconnaissance satellite program did not proceed in absolute secrecy. To increase secrecy, on 31 August 1960, Eisenhower ordered the CORONA program placed under a civilian-directed office in the Department of the Air Force. Joseph V. Charyk had the unique opportunity to bypass the chain of command when he took over leadership of the secret Satellite Reconnaissance Program Office, located behind door 4C1000 on the Pentagon's fourth floor.[24] A small group of military officers and government civilians reported directly to Charyk and he to the Secretary of Defense, bypassing even the Secretary of the Air Force, under whom he nominally served. After the change of national leadership in early 1961, Charyk stayed on as Director of the National Reconnaissance Office, leaving two years later to run the new Comsat Corporation.[25] In September, the CIA and DoD formally established the National Reconnaissance Program, consisting of all satellite and aerial reconnaissance programs, secretly creating the NRO by classifying its very existence. An accompanying agreement between DoD and the CIA gave joint leadership responsibility to the Director of the NRO (Charyk, who also served as the Undersecretary of the Air Force), and the CIA's Deputy Director for Plans (Richard M. Bissell, Jr).[26]

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[24] NRO's main Pentagon office, in rooms behind door 4C1000, earned them the somewhat pejorative and medieval nickname "Forcey One Thousand."

[25] For a brief overview, see David J. Whalen, "Billion Dollar Technology: A Short Historical Overview of Origins of Communications Satellite Technology, 1945-1965," especially 110-14, in Andrew J. Butrica, *Beyond the Ionosphere: Fifty Years of Satellite Communication* (Washington: NASA, SP-4217, 1997).

[26] R. Cargill Hall, *The NRO at Forty: Ensuring Global Information Supremacy* (Chantilly, VA: National Reconnaissance Office, 2000), 2-3; Cyrus Vance, Deputy Secretary of Defense, Department of Defense Directive Number TS 5105.23, "National Reconnaissance Office," 27 March 1964, in *Exploring the Unknown*, vol. 1, 373-374.

A May 1962 agreement between the Director of the CIA, John A. McCone, and the defense secretary, which Deputy Defense Secretary Roswell L. Gilpatric signed, outlined basic policy for the National Reconnaissance Office. The CIA and DoD agreed that the NRO would directly respond "to, and only to, the photographic and [redacted] collection requirements," as determined by the United States Intelligence Board. The CIA and DoD also agreed that the reconnaissance mission schedule would be the NRO's sole responsibility, and that the NRO would assign operational control for individual projects under the National Reconnaissance Program to the Department of Defense.[27] In March 1964, CIA Director William Raborn and Deputy Defense Secretary Cyrus Vance signed the current NRO charter, DoD Directive TS-5105.23, the only one partially declassified. The two agencies agreed to make the NRO a separate agency within DoD, giving it responsibility for the management of the National Reconnaissance Program, not operation of satellite programs. The directive gave the NRO director responsibility "for consolidation of all DoD satellite and air vehicle overflight projects for intelligence into a single program defined as the National Reconnaissance Program, and for the complete management and conduct of this Program in accordance with policy guidance and

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With the exception of this directive, the defense department prohibited using the terms National Reconnaissance Office, National Reconnaissance Program, or NRO in any document. Any reference had to be using the phrase "Matters under the purview of DoD TS-5105.23."

[27] John A. McCone, Director of the CIA, and Roswell L. Gilpatric, Deputy Secretary of Defense, "Agreement Between Secretary of Defense and the Director of Central Intelligence on Responsibilities of the National Reconnaissance Office," 2 May 1962, NRO, 2/A/0036.

decision of the Secretary of Defense."[28] TS-5105.23 did not give the NRO responsibility for operations, only management of the National Reconnaissance Program. The NRO interpreted "conduct" to mean its charter also bestowed on it *operational* responsibility for reconnaissance satellites. In the following years, the NRO and its contractor teammates designed, built, launched, *and* operated all the nation's reconnaissance satellites.[29]

The NRO gradually expanded its control over satellite reconnaissance, while keeping a tight lid on security for the National Reconnaissance Program. In 1963, Eugene Kiefer, Deputy NRO Director, believed that the CORONA program had regressed. After years of steady improvement, the program experienced a string of failures, indicating the need for some major changes in program management. In one major change, Col. Lee Battle, the air force officer who had been running the reconnaissance satellite program in Los Angeles for some time, moved to Schriever's headquarters in the Washington area. Kiefer wanted to pick technically competent, responsible individuals, one from CIA and one from the air force, to control the reconnaissance satellite program in a team fashion as it had been at the outset, when air force Col. Frederic C. E. Oder ran the weapon system program office and CIA officer Charlie Murphy (also an air force officer at the time) ran the CIA field detachment and

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[28] DoD Directive TS-5105.23, in Logsdon, *Exploring the Unknown*, vol. 1, 373-5.

[29] Hall, *The NRO at Forty*, 4.

controlled the missions.[30] Kiefer ignored the technically competent, responsible individuals already involved in the program, even at the lowest levels of operations, not hiring any of them to replace Colonel Battle. Most operators did not have clearance for the CORONA program, so they did not know the actual mission of the satellites they operated. This early cadre of experienced personnel could have offered their technical and operational expertise for development of the system if NRO had allowed them to participate in the National Reconnaissance Program beyond their limited role as satellite operators.

Their expertise also would have been useful if the CIA's proposal for another command and control site had borne fruit. In an effort to devise a more effective means of exploiting the limited film supply available in CORONA vehicles, the CIA discussed establishing an additional satellite command and control facility at one of the tracking stations to give the Field Test Force Director, the actual reconnaissance mission commander, more selectivity of the areas of which the camera took pictures. Without the tracking station control center, the Field Test Force Director preprogrammed 30 percent of the film, including the camera "ON/OFF" decisions for the entire first five passes over the USSR, when the satellite orbited out of range of the United States-based tracking network. Increased selectivity allowed expenditure of the limited film supply in areas of primary interest, areas of best weather, and areas not previously covered. With a tracking station-based control center, the mission commander committed only 10 percent of the

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[30] MEMO, Eugene P. Kiefer, Deputy NRO Director, to Lt. Gen. Marshall S. Carter, Deputy CIA Director, SUBJ: "Technical Management of CORONA Program," 9 July 1963, NRO, 1/A/0039.

film at once.[31] Most people who worked on the CORONA program did not have a clearance for the photoreconnaissance mission, so significant problems down the line developed for the satellite operators.

By not clearing more people for the CORONA program, the CIA made its job more difficult. As a rule, the CIA did not grant the level of access given to technical experts like then-Captains McCartney, Lewin, and Crews, the first air force officers to fly a reconnaissance satellite. The air force had responsibility for the health and status of the vehicle, but the NRO and the CIA tightly controlled payload operations. The CIA provided the air force with the calibration data and telemetry charts from the Lockheed Advanced Projects (AP) facility in Menlo Park, California, where contractors assembled the reconnaissance satellites. "[H]ighly trained Lockheed technicians under Government contract" conducted diagnostic analysis of telemetry at AP all the time. When a satellite problem arose, AP engineers immediately went to the Satellite Test Center to provide their expertise but provided so little help on a daily basis that air force operators accused the CIA of withholding information that they needed for launch and recovery. The CIA refused to provide payload data, believing the air force wanted to duplicate "a payload analysis that was already adequately covered by a Government-funded effort involving experienced and competent personnel at the CIA facility" in Menlo Park.[32]

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[31] MEMO, Colonel [Name Redacted], Acting Chief, DPD-DD/P, SUBJ: "[Redacted] Tracking Station for CORONA," 15 June 1960, NRO, 1/C/0019.

[32] MEMO for the Record, Lt. Gen. Carter, Deputy CIA Director, SUBJ: "Meeting with Mr. Vance and Dr. McMillan on Thursday, 25 March [1965]," 26 March 1965, 1-2, NRO, 1/A/0096; MEMO for the Record, [Name Redacted], Chief, Special Projects Staff, SUBJ: "Fact Sheet Regarding the Allegation that Since August 1964 CIA Has Been

Difficulties between the CIA, the NRO, and the air force grew out of a period when "less than vigorous top-level leadership on the CIA side of CORONA" gave the air force, led by Air Force Undersecretary and therefore NRO chief Brockway McMillan, more of a lead role in the reconnaissance satellite business. The CIA accepted a freer air force hand as long as the CORONA program suffered no major setbacks. During 1962, the air force successfully orbited seventeen payloads, retrieving fourteen of them, including 69 percent of the film launched. When operations went downhill during 1963 with a string of launch failures and film recovery dipping to 50 percent, Dr. McMillan proposed that the air force completely take over the CORONA program. At that point, the CIA stepped back up to the plate. Senior members in both CIA and the White House did not intend to make the National Reconnaissance Program a strictly military responsibility, so the CIA held onto its role in satellite reconnaissance.[33] Satellite reconnaissance remained too important to leave to the generals.

Army Lieut. Gen. Marshall S. Carter, the CIA's deputy director, worried about NRO boss McMillan making "a clear-cut effort to run the CIA out of the satellite business and mak[ing] this critical intelligence collection system a complete blue-suit operation." Carter believed McMillan attempted to gain control of the reconnaissance program, using the desire to acquire as much knowledge as possible about the vehicle as a smoke screen to cover his real intentions. McMillan suggested in a conversation with General Carter that air force operators needed to have not only telemetry on health and

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Withholding Payload Data from the Air Force in the CORONA Program," 25 March 1965, NRO, 1/C/0099.

[33] CIA Office of Special Projects, *History*, 1 June 1973, NRO, 2/A/0075.

status but also calibration data for the CORONA camera. General Carter refused to give the air force operators the calibration data, arguing that they would not know what to do with the data if they had it, and that he "had no intention of establishing or allowing to be established a separate diagnostic, analytical function by an agency not having responsibility for the payload." Carter ended the meeting with McMillan without giving any ground on the payload issue, certain that the bureaucratic sparring would "continue as long as McMillan, [redacted], [Paul] Worthman, [Frank] Buzard and [Charlie] Murphy are in the act."[34] Clearly, the CIA intended to stand in the way of the air force's ability to regularize space operations.

In a 1965 memo entitled "Examples of the Air Force Impacts on the CORONA Program," the CIA tried to show how the NRO had "reached the heights of irresponsibility" by attempting to disable the Advanced Projects facility team and "inject into the program an inexperienced [redacted] element with an unprepared and inadequate systems [sic] of operation." For example, the NRO's meddling in the smallest of details caused "undesirable duplication, increased cost[, and] unnecessary delays without contributing anything which, at least in the payload area, has proved beneficial." While acting as project engineer, reviewing all wiring changes, the NRO failed to make use of the available resources that made the program a success, while the CIA had to justify its existence in the CORONA Program through large numbers of meetings, especially design

[34] MEMO for the Record, Lt. Gen. Marshall S. Carter, Deputy CIA Director, SUBJ: "Meeting with Mr Vance and Dr McMillan on Thursday, 25 March [1965]," 3-4.

and specification reviews.[35] The CIA memo further criticized air force operators for ignoring the CIA operations chief during Mission 1013, launched 2 November 1964.[36] Shortly after launch, test controllers and the Field Test Force Director determined a problem with the vehicle. After studying the telemetry, the CIA's expert confidently reported normal payload operation, ordering the tracking station, through the Field Test Force Director, to command the payload "ON." When bad telemetry came back again, the Field Test Force Director and the satellite program office in Los Angeles ordered the payload turned "OFF." The CIA's operations chief failed to remedy the situation before the vehicle went over the horizon and out of commanding range from the tracking station. The lack of communication resulted in the loss of important intelligence information.[37]

The CIA convinced itself that the air force, which made up the majority of the small NRO staff, controlled the National Reconnaissance Office and that the reconnaissance satellite program badly needed CIA guidance. A 1965 memo condemned NRO attempts to "undermine" the Advanced Projects facility community's confidence in the CIA's ability to guide the CORONA program, providing a litany of examples of how the air force failed to support the CIA. Satellite program officer Captain Johnson (subsequently Major Johnson of the National Reconnaissance Office, according to the report) directed Lockheed to deviate from "proven" environmental tests on three

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[35] "Examples of the Air Force Impacts on the CORONA Program," 31 March 1965, 1-4, NRO, 1/C/0100.

[36] For details of every CORONA mission, see Peebles, *Corona*, Appendix 1.

[37] "Examples of the Air Force Impacts on the CORONA Program," 9-10. According to Peebles, Appendix 1, both cameras failed on orbit 52, though the air force did recover both reentry vehicles.

CORONA missions, resulting in a static discharge building up on the film, known as "the corona effect." The second of the three missions, CORONA Flight 75 in December 1963, Mission 9062, produced largely unusable pictures due to the corona effect.[38] When the CIA technical representative forced the return of the third mission to the AP facility, retests of the equipment revealed that the film system also had a bad roller and would have produced bad pictures. The CIA saw this incident as proof that the CIA needed to lead the CORONA program.

The memo's anonymous author perceived NRO and air force satellite program office personnel as too removed from the intelligence mission and more interested in launch schedules and recoveries than in the quality of the pictures. For example, at a meeting in early 1965, a sharp exchange took place between Colonel Buzard of the National Reconnaissance Office staff and an anonymous member of the CIA staff. Colonel Buzard apparently stated that the National Reconnaissance Office had scheduled sixteen CORONA launches for 1965 and that they intended to meet the schedule. "Mr. [Redacted] made it clear to Colonel Buzard that CORONA was an intelligence reconnaissance program and that the missions would be flown in response to intelligence requirements, not in response to pre-established Air Force launch schedules."[39] Buzard says the memo author took his comment out of context:

> I have absolutely no recollection of any such meeting or of making such a comment. I have read that comment in another document somewhere, but it was made at a much earlier date when it was [alleged] that the Air Force wanted to launch on a regular schedule to reduce overtime etc. All this was at a time when we in the Project Office

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[38] See Day, et al., *Eye in the Sky*, esp. 69-70.

[39] "Examples of the Air Force Impacts on the CORONA Program," 6.

> were always launching just as often and as quickly as we could get the hardware ready to go.[40]

Naming the air force specifically, the memo criticized NRO attempts to expand its control over CORONA, something the CIA wanted to prevent.

NRO Director McMillan did not give up on his quest for greater control of the satellite reconnaissance mission. On 30 November 1964, he directed the NRO to handle all premission, mission, and postmission CORONA messages exclusively at their operations center in Washington and at the Satellite Test Center on the West Coast. Further, he put the mission command post at the STC and made changes to the operations manual. The next day, the NRO added the STC to the list of organizations receiving CORONA message traffic and deleted the CIA's Advanced Projects facility in Menlo Park. The CIA responded in horror, saying that the Satellite Test Center could not provide adequate support without significant additional training, including two to four months of necessary computer software upgrades. CIA headquarters required field units to obey the orders as if the 30 November McMillan memo had never happened. They perceived the McMillan memo as "the climax of a power grab attempt within government circles. The actions taken were not only poorly staffed and technically unrealistic, but they demonstrated a much greater concern on the part of the D/NRO [McMillan] for the political management policies than for intelligence reconnaissance operations."[41] The CIA had guessed right: McMillan had again attempted to expand NRO's sphere of

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[40] Frank Buzard, electronic mail to author, SUBJ: "Feb1965 Mtg.," 28 Aug. 2001. According to Buzard, "I just checked the record and we did launch 14 in 1965 (one may have been a non CORONA mission which was destroyed by Range Safety because they thought it was going off course)."

[41] "Examples of the Air Force Impacts on the CORONA Program," 7-9.

influence, a sphere that included the Air Force Satellite Control Facility. As former CIA officer Herbert Scoville put it later in an interview with Jeffrey T. Richelson, McMillan's most important talents included "empire-building."[42]

General Schriever felt that the NRO's attempt to expand its sphere of influence not only extended beyond its original mandate, but also did more harm than good by keeping the operators out of the loop. In effect, this separation kept them from developing an intimate knowledge about the technology about which they should have known the most. Schriever presented the flag on board DISCOVERER XIII to President Eisenhower, but no one felt he had a need to know that DISCOVERER XIV carried a camera. In fact, Schriever believes, satellite command and control suffered during the NRO's expansion. Furthermore, Schriever expressed in a 2001 interview with the author that the NRO should be a policy-making organization, not a hardware organization. Making the NRO a bureaucracy with operational responsibilities "was the wrong move to take, because the operator was really taken out of the loop. If you look at all the 117L babies, they were practically all gobbled up by the NRO. That, plus the fact that you find people that are always trying to protect their rear ends--'what's been' instead of 'what we can get'--and that sure as hell happened in space." Schriever wanted to restrict the National Reconnaissance Office's area of responsibility. Because about 90 percent of the NRO's staff came from the air force in the early days, the air force if given a chance,

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[42] Jeffrey T. Richelson, "Undercover in Outer Space: The Creation and Evolution of the NRO, 1960-1963," *International Journal of Intelligence and CounterIntelligence* 13 (March 2000), 335.

could have done as good a job operationally as the NRO, or, in Schriever's words, "maybe better."[43]

To be fair, in the early 1960s the National Reconnaissance Office did not behave like the massive bureaucracy that typifies it today. In the early 1960s, most of the bureaucratic squabbles and jockeying for power went on at the highest levels of the government. The CIA officer in charge in Palo Alto, air force Lt. Col. Charles Murphy, says the NRO acted largely transparently to the satellite operators. The CIA and air force people involved in the program in California had an excellent relationship. They did not have to call back to Washington and ask permission to make decisions; they just made the decisions, even if they planned something for the first time. In fact, the program succeeded because the working people--wrench turners and engineers and the people making decisions in the field--ignored the bureaucratic squabbles and did what they had to do to accomplish the mission, with the AFSCF caught in the middle.[44]

The NRO did reasonably well at gathering strategic intelligence while delaying the air force from normalizing space operations. Because the NRO had a specific charter to acquire strategic intelligence, it actively kept other organizations, particularly the air force, whose legal mandate included acquiring strategic reconnaissance, out of the space operations arena.[45] The AFSCF had no choice but to go along for the ride during the bureaucratic tug-of-wars. In the midst of the bureaucratic squabbling in Washington, the

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[43] Schriever interview by author.

[44] Murphy interview by author.

[45] Schriever interview by author.

air force tried to take as much control over satellite operations as it could in California and throughout the network by standardizing procedures and operating the AFSCF much like any "normal" flying unit.

Overcoming Organizational Momentum

As they all scrambled for a piece of the new space reconnaissance pie, each of the major players tried to grab control of the Air Force Satellite Control Facility. For the AFSCF, the greatest organizational challenge stemmed from the air force leadership's belief in its singular capability to carry out the military space mission, while other groups, as eager for a piece of the space budget, tried to hold onto or expand what they had. To hold onto its position as the preeminent service for space, the air force tried to acquire complete authority for missile and space-related management and the opportunities extending into satellite command and control as well.

On 16 November 1963, Secretary Robert S. McNamara informed the air force that he wanted significant and "mandatory" changes in the management of department of defense missile and space ranges.[46] He saw an "obvious need" for improvements in the management structure of DoD ranges because "successful performance of assigned missions has occurred despite, rather than because of, the management structure."

[46] MEMO, R. S. McNamara, SUBJ: "Management and Organization of DoD Ranges and Flight Test Facilities," to the Secretaries of the Army, Navy and Air Force, 16 Nov. 1963, 1, AFSPC/HO, Box 7-2-1. See also: Gerald T. Cantwell, *The Air Force In Space: Fiscal Year 1964* (Washington, DC: USAF Historical Division Liaison Office, June 1967), 13-14, AFSPC/HO; Press Release, "Major Management Reorganization for Ballistic Missile and Space Test Range Facilities Announced by Department of Defense, For Release 10:00 PST," 20 Nov. 1963, AFSPC/HO, Box 7-2-1.

Noting that several agencies had responsibility for global tracking, McNamara sought to centralize all command and control into one agency to help resolve the "interface" problems between the Atlantic Missile Range, Pacific Missile Range, and the Air Force Satellite Control Facility.[47] Thus, McNamara saw the need for a central organization that could preside over the operations and planning of military space and missile command and control. In the American electric power generation business, management created holding companies to help organization. In this case, government managers simply invented a larger organization responsible for all space and missile command and control, calling it the National Range Division (NRD).

The air force stood to benefit from McNamara's efficiency movement in the defense department when he ordered the consolidation of some major space and missile test ranges under air force management. The navy lost a major shore installation when McNamara combined the Naval Missile Facility at Point Arguello, California, and Vandenberg AFB, into a single air force base. The secretary also tried to "nationalize" the AFSCF, making it responsible for "management and operation of a world-wide satellite tracking and control facility for all DoD programs." McNamara laid out his direction in a memo to the service secretaries. "The Air Force shall establish a central authority for the combined planning of ICBM and space vehicle launch area ranged instrumentation and satellite on-orbit control facilities to include Cape Canaveral and

[47] MEMO, R. S. McNamara, SUBJ: "Management and Organization of DoD Ranges and Flight Test Facilities," to the Secretaries of the Army, Navy and Air Force, 16 Nov. 1963, 2-3.

Point Arguello/Vandenberg launches, as well as remote tracking stations world-wide."[48] McNamara directed that the AFSCF come under the new authority no later than 1964.

The air force, therefore, prepared to take control of the new National Range Division. On 3 December 1963, Air Force Chief of Staff General Thomas D. White wrote General Schriever and SAC Commander-in-Chief General Thomas Power, that the

> assignment of these responsibilities to the Air Force is predicated upon our establishment of a single manager capability to centrally plan for and manage the execution of test programs with optimum economy. . . . The several instrumentation networks, now being separately planned and managed by the Ranges and [Air Force] Satellite Control Facility, must be managed in the future as a group of test facilities and networks to most economically serve all DoD users.[49]

General White considered McNamara's decision a major milestone in the "furtherance of Air Force objectives and mission in aerospace" because it virtually promised the air force the role as the defense department's executive agent for space, guaranteeing bigger budgets.

Maj. Gen. Leighton I. Davis, Commander of the Air Force Missile Test Center at Patrick AFB, Florida, chaired the National Range Implementation Group, chartered to simplify the management of the military ranges. General Davis assumed that defense department and air force directives required establishing a single, field-level organization to coordinate and integrate the Atlantic Missile Range, Pacific Missile Range and the AFSCF into one "National Range Division," which he assumed would be assigned to

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[48] Ibid., 3-4.

[49] LTR, Gen. White, SUBJ: "Management and Organization of DoD Ranges and Flight Test Facilities," to Gen. Power and Gen. Schriever, 3 Dec. 1963, AFSPC/HO, Box 7-2-1.

General Schriever's Air Force Systems Command.[50] Quickly Major General Davis received responsibility for the Atlantic and Pacific missile test ranges.

The issue of the Air Force Satellite Control Facility did not go away quite as easily as the missile ranges. Following McNamara's direction, Lt. Gen. Howell M. Estes, Jr., ordered General Davis to take command of a provisional National Range Division with headquarters at Andrews AFB, where General Schriever's Air Force Systems Command also had its headquarters. In his order, General Estes did not include the AFSCF in the new NRD, leaving it as part of the Space Systems Division in Los Angeles. He asked General Davis to study the "feasibility" of transferring the AFSCF to NRD.[51] Air Force Secretary Eugene M. Zuckert wrote McNamara that the air force would study "the time-phasing for complete transfer" of the AFSCF into NRD.[52]

McNamara took one look at the air force's plan for the implementation of the National Range Division proposal, and believing the service was stalling on the decision to move the Air Force Satellite Control Facility, offered a compromise. "We expect the Air Force to assign a single agency the responsibility for management and operations of world-wide satellite tracking and on-orbit control facilities for all DoD programs. . . . We anticipate that the current organization now responsible for the Satellite Control Facility

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[50] "Task Group Charter," National Range Implementation Group, 13 Nov. 1963, AFSPC/HO, Box 7-2-1.

[51] LTR, Gen. Estes, SUBJ: "Management and Organization of the National Range," to Gen Davis, 1 Jan. 1964, AFSPC/HO, Box 7-2-1.

[52] LTR, Secretary of the Air Force, SUBJ: "Management and Organization of DoD Ranges and Flight Test Facilities," to the Secretary of Defense, 3 April 1964, AFSPC/HO, Box 7-2-1.

will form the nucleus of that agency."[53] Zuckert followed orders and issued a directive to reorganize the AFSCF under the new management structure.[54] But Air Force Systems Command ignored his order, leaving the AFSCF outside the National Range Division.

The air force resisted McNamara because the service had organized the two major functions of satellite command and control separately. The satellite command and control community performed two major activities: satellite command and control operations in response to satellite program requirements and planning for the development and improvement of the satellite command and control system. The 6594th Aerospace Test Wing in Sunnyvale handled satellite operations and the Deputy for Space Test Operations at Space Systems Division in Los Angeles handled planning. Undersecretary of the Air Force and NRO chief Dr. Brockway McMillan ordered the combination of all operations and planning activities under a single organizational element, headed by a general officer, instead of the two separate but equal colonels. This new general officer position had responsibility for the overall direction of operation of all the remote tracking stations as well as for planning and implementation of future actions for improvement or growth of the network.[55] The air force Chief of Staff concurred with McMillan, seeing a new way for the air force to get its organizational house in order

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[53] LTR, Secretary of Defense, SUBJ: "Management and Organization of DoD Ranges and Flight Test Facilities," to the Secretary of the Air Force, 25 April 1964, AFSPC/HO, Box 7-2-1.

[54] LTR, Under Secretary of the Air Force, SUBJ: "Air Force Satellite Control Range," to the Vice Chief of Staff, 14 Aug. 1964, AFSPC/HO, Box 7-2-1.

[55] LTR, Under Secretary of the Air Force, SUBJ: "Air Force Satellite Control Range," to the Vice Chief of Staff, 14 August 1964, AFSPC/HO, Box 7-2-1. Brigadier General King was the first to hold the combined position.

while continuing to fight the National Range Division idea.[56]

The air force also resisted McNamara, not in a bureaucratic grab for turf, but because of the influence of the Air Force Satellite Control Facility's primary customer, the National Reconnaissance Office. The NRO dominated the use of the AFSCF. McMillan, who not only served as Undersecretary of the Air Force but also as NRO Director (although DoD kept that title classified), refused to release the AFSCF to the new National Range Division. Once satellite "programs other than the specially classified ones" became the majority of AFSCF support activities, McMillan said he would consider releasing the network to NRD.[57] McMillan, in effect, wanted to consolidate the AFSCF, the sole provider of satellite command and control for defense department space programs, with the CIA's Office of Special Projects--the organization in the CIA responsible for developing reconnaissance satellites--under one organization, preferably the Air Force's Space Systems Division in Los Angeles.[58] McMillan made a play much broader than simply managing space and missile command and control. McMillan's plan tried to take the entire reconnaissance satellite business for the air force and NRO.

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[56] LTR, Assistant Vice Chief of Staff, SUBJ: "Organization of Satellite Control Resources of the NRD and the SSD Satellite Control Range," to Air Force Systems Command, 27 May 1964, AFSPC/HO, Box 7-2-1.

[57] LTR, Under Secretary of the Air Force, SUBJ: "Organization of Satellite Control Resources," to the Director of Defense Research and Engineering, 14 Aug. 1964, AFSPC/HO, Box 7-2-1; King interview by author.

[58] Gerald T. Cantwell, *The Air Force In Space: Fiscal Year 1965* (Washington, DC: USAF Historical Division Liaison Office, April 1968), 3-4.

The National Range Division and the Space Systems Division (SSD) quickly began a paper war, throwing their opinions at each other. General Davis grew understandably upset at this violation of his mandate from McNamara. In a 1964 issue paper, he reiterated NRD's differences with SSD and cited the Secretary of Defense's memo as evidence that NRD should have all responsibility for planning authority.[59] SSD's response: engineers designed and wired on-orbit stations for operation as integrated units in support of unique or of very similar missions, not geographically for logistical support. SSD believed, therefore, that the agency carrying out the mission had to have complete management of mission, communications, logistics and administration. SSD disagreed with NRD's plan for division on a functional basis. Under NRD's plan, the Air Force Satellite Control Facility would manage and operate all equipment for satellite command and control but the stations would be grouped together geographically for logistical and administrative support. Where NRD could assist administratively and logistically, as in the case of Mahe, Seychelles, which the Eastern Test Range at Patrick could support, NRD would administer the station. Otherwise, the AFSCF could manage and operate its own stations. General Davis thought NRD had the most logical position and could fulfill the Secretary of Defense's directive to improve efficiency in the DoD.[60] In effect, a classic bureaucratic turf war raged inside the air force, which had organizational responsibility for both the Air Force Satellite Control Facility and the

[59] Draft Issue Paper, "NRD/SSD Support Planning Relationships," n.d., MT 64-85104, 1-2, AFSPC/HO, Box 7-2-1.

[60] Ibid., 3-16.

National Range Division, as well as co-responsibility with the CIA for the National Reconnaissance Office.

In the end, the influence of agencies outside the air force pushed the issue of control of the AFSCF to a final resolution. The two sides came to an agreement and settled the internal air force squabble with a memorandum of agreement, which Maj. Gen. Ben I. Funk, Space Systems Division Commander, and General Davis, National Range Division Commander, both signed. The agreement said, in effect, that the Space Systems Division retained command and overall technical and managerial control of the Air Force Satellite Control Facility and that the National Range Division would leave them alone.[61] The NRD remained responsible for the missile ranges for a time, but the air force disestablished it in the late 1960s, returning to the older methods of management.

The AFSCF had won a major battle to stay independent of any national range establishment. Now one stronger organization had responsibility for both planning and operations of air force satellite command and control, and a one-star general commanded it. McNamara's attempt to overcome the organizational momentum in the Air Force Satellite Control Facility failed when the National Range Division's attempts to take over satellite command and control proved less powerful than the desires of the National Reconnaissance Office.

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[61] Memorandum of Agreement between the Commanders of the Space Systems Division and the National Range Division (Provisional) of the Air Force Systems Command, signed Feb. and Mar. 1964, AFSPC/HO, Box 7-2-1.

Summary

The air force overcame management challenges by emphasizing the Air Force Satellite Control Facility's unique place in the department of defense space mission. The AFSCF did not use tracking range radars for IRBM and ICBM tests off the Atlantic or Pacific coasts. These ranges launched rockets and missiles but did not have the equipment to handle command and control and satellite trouble-shooting. The AFSCF was a different kind of range, a concept lost on many people. Once the air force convinced the DoD leadership of this significant difference, the AFSCF held onto its unique place in the service. In addition, the unique relationship with the users who existed outside the DoD, in particular, the NRO whose partner, the Central Intelligence Agency's Office of Special Projects, made it known that they patronized the AFSCF because their money made satellite command and control work.[62] Management set the pace for change, not the technology, further illustrating the social construction of this large technological system.[63]

The manager-entrepreneurs who ran the Air Force Satellite Control Facility and the primary customers who justified its existence built momentum into the system. The AFSCF did not evolve autonomously but its institutional and technological momentum proved difficult to overcome. The Space-Ground Link Subsystem served both parties,

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[62] King interview by author.

[63] For example, in the 1980s, the AFSCF faced another major organizational reverse salient in the creation of Air Force Space Command, the U.S. Air Force's attempt to make space as commonplace as flying airplanes and to grab a bigger piece of the space budget. For a short time after the creation of the new space command, the AFSCF remained in the Air Force test community. Eventually, though, the Air Force folded the AFSCF into the operational community because of the increasing importance of the operational space mission and the decreasing importance of the space test mission.

advancing satellite command and control technology while enabling the development of even more sophisticated satellites. The special relationship with the NRO continued as the AFSCF paid homage to its patron, often at the cost of supporting such other important national space priorities as the military's own weather satellites. In the pressure cooker of the space program in the 1960s, institutional momentum diverted well-meaning proposals into a move to isolate space operations further from the rest of the air force operations community, despite the presence of a common-user Air Force Satellite Control Facility.

CONCLUSION

*INVENIEMUS VIAM VEL FACIEMUS**

> My own views are that we can win the race for space if we do so desire. And I feel we must win it, so that all humanity can profit from these benefits, which God has surely placed within the reach of man.[1]
>
> -- Brig. Gen. Homer A. Boushey, 23 April 1958
> Air Force Deputy Director of R&D

> The tracking and data-acquisition system serving "ETR," the Eastern Test Range, makes this miracle [spaceflight] possible. It is probably even more complex than the space vehicle whose performance was just announced [Mariner II].[2]
>
> -- Dr. Wernher von Braun
> Director, George C. Marshall Space Flight Center

This story ends in the year 1969 because in that year the Air Force Satellite Control Facility became a complete satellite command and control system. After 1969, the changes in the system became less qualitative, more regular, and even to some extent predictable. In addition, analysis of this concrete period in the history of the Air Force Satellite Control Facility is more useful than superficial coverage of the whole history of air force satellite command and control, which would be out of date by the time the project is completed, anyway.[3]

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[1] Homer A. Boushey, U.S. Air Force Deputy Director of Research and Development, 23 April 1958, in *Astronautics and Space Exploration*, 526.

[2] Wernher von Braun, *Space Frontier* (New York: Holt, Rinehart and Winston, 1963), 69.

[3] For a detailed list of important dates in Air Force Satellite Control Facility history, see Roger A. Jernigan, *Air Force Satellite Control Facility: Historical Brief and*

After 1969, changes occurred in the Air Force Satellite Control Facility in much smaller increments than the dramatic improvements of the 1960s. Few organizational changes took place. Although the AFSCF changed names a few times well into the 1990s, it continued as the primary, but no longer sole, provider of satellite command and control services to the military and the National Reconnaissance Office. In addition, with the rise in the 1970s of new building codes and sensible thinking about earthquake hazards (the Sunnyvale facilities sat right on the San Andreas earthquake fault), and with the rise of NASA's space shuttle in air force planning in the early 1980s, the service built a newer and more secure satellite control facility outside Colorado Springs. The air force did not pilot the space shuttle as it originally envisioned, but the Colorado Springs facility, first known as the Consolidated Space Operations Center and now known as Schriever Air Force Base in General Schriever's honor, eventually became the center of all air force satellite command and control operations.

In addition, this story ends here because few technological changes took place after 1969. By the end of the decade, the air force had its system of satellite command and control in place, having reached its goals using whatever available or appropriate means it could. The most dramatic changes included the introduction of new computer technology. The Advanced Remote Tracking Station computers accomplished tasks that one hundred or more people had performed at the original tracking stations and reduced the number required to two. Under consideration in the year 2001 was a proposal to eliminate all the people at the tracking stations except for maintainers. This technical

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Chronology, 1954 – Present (Sunnyvale AFS, CA: AFSCF History Office, 1983), AFSPC/HO.

modification would automate the last of the operations functions, finally reducing the number of "antenna drivers" in the air force satellite command and control system to zero. In 2001, the air force also considered a so-called "Lights Out" plan that would involve a system similar to NASA's use of tracking and data relay satellites, all but eliminating the need for any ground tracking stations worldwide.[4] Such a system setup raised space dependence questions, such as satellite vulnerability to enemy action.

To explore the evolution of the Air Force Satellite Control Facility, this study has used a model of the social construction of technology articulated by historian Thomas Parke Hughes.[5] His model serves well in meaningfully describing the way human beings created a large technological system for satellite command and control. Another reason for using the model was to add something to the model itself, further refining and possibly expanding it. Analysis of the AFSCF has helped to refine and expand the model by adding a new perspective. This dissertation is hardly the first comprehensive look at an artifact produced largely by the federal government.[6] In its analysis of the evolution of a large technological system solely designed to meet governmental needs, it follows the lines of Hughes's own power networks or Boston's Central Artery/Tunnel.[7] In addition, this dissertation adds to the body of knowledge showing that there is no need for

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[4] Warren Pearce, electronic mail to author, SUBJ: "RE: New DoD Space Policy Letter," 10 May 2001.

[5] For a short explanation of the model, see Hughes, "The Evolution of Large Technological Systems," 51-82.

[6] See especially Glenn Bugos, *Engineering the F-4 Phantom II: Parts into Systems* (Annapolis: Naval Institute Press, 1996).

[7] See Hughes, *Networks of Power* and Hughes, *Rescuing Prometheus*, 197-254.

a "Eureka! moment" in the evolution of technological systems, particularly when management plays a more important role in the system's evolution than inventors or engineers, as the case of the Air Force Satellite Control Facility illustrates.

In the model's first phase, that of invention, inventor-entrepreneurs solved the critical problems associated with making satellite command and control work. No "Eureka! moment" sparked the birth of the AFSCF because teamwork in engineering development built the system. If one must look for an inventor or Hughes's inventor-entrepreneur, then one might look for one in the organizations that had overall responsibility for the first American reconnaissance satellites: the Western Development Division and its contractor-partner, Lockheed Aircraft Corporation. These independent inventors had the insight to distance themselves from the larger air force R&D organization--the air force's Air Research and Development Command, in particular, but the air force procurement system, in general. Large organizations vested in existing technology rarely nurture inventions that by their nature contribute nothing to the organization and even challenge the status quo. The flying air force, uninterested in new technological systems for reconnaissance, did not contribute to the development of this new technology, which all but made airplane-based reconnaissance obsolete. The normal weapons procurement system could not bring a spectacular new system on-line as quickly as the United States needed photoreconnaissance of the USSR in the early days of the Cold War.

Also during the invention phase, the inventors, independent and free from the constraints of large industrial or governmental organizations, had a free hand in choosing solutions to the problems they encountered. The air force went outside, to a group of

scientific advisors who represented the best minds in the nation, and to the RAND Corporation, finding answers to questions the air force could not answer alone. General H. H. Arnold gave Dr. Theodore von Kármán room for maneuver and *Toward New Horizons* became the blueprint for the United States Air Force for the rest of the twentieth century. General Curtis LeMay gave Douglas Aircraft's Research and Development group broad authority to investigate the usefulness of satellites. RAND's series of reports on the utility of a "World-Circling Spaceship" eventually became the first technical reports in the history of satellite command and control. Just as important, General Schriever did not report through normal air force channels, but instead reported with the highest national priority directly to the Secretary of the Air Force and the president of the United States. Schriever's wide latitude to develop the ICBM and the reconnaissance satellite independently helped achieve these feats far quicker (although certainly not any cheaper). The air force purposely put the Western Development Division on the West Coast, not just to get it closer to the nation's airplane manufacturers, but also to get it out of Washington.

During system development, the model's second phase, the social construction of technology became clear as engineers transformed the invention of satellite command and control into an innovation. They embodied in the Air Force Satellite Control Facility the economic, political, and social characteristics it needed to survive by turning their ideas about satellite command and control into a command and control system. Then they instilled economic and social characteristics into the AFSCF to create a system that fended off rivals. Finally, with the development phase essentially over, the AFSCF expanded its role in the air force space program to increase its indispensability.

By 1960, during the innovation or third phase, the product had come into use. The Subsystem H engineers, given a free hand, used state-of-the-art equipment, creating a satellite command and control system before the first satellite launch absolutely necessary for the early reconnaissance program. Satellite-based reconnaissance, a radical idea, needed satellite command and control, essentially a conservative idea, which used older practices borrowed from the ICBM test environment. Meanwhile, at the urging of the contractors and the air force, the size of the system expanded. Those presiding over Subsystem H, the Air Force Ballistic Missile Division and Lockheed, developed satellite command and control as much as possible, while numerous players each attempted to add an ounce of their own control to the system until the air force finally won the day. By 1961, managers, both contractors and military officers, had replaced the inventors of satellite command and control. After successfully arguing that a service organization should be responsible for command and control of the WS-117L reconnaissance satellite program, not an operational nuclear command, the air force created the 6594th Test Wing (Satellite) to perform that service, thus retaining satellite command and control as a critical function for the air force test community to perform.

As the system expanded into the fourth phase of the Hughes model, the growth phase, problems developed, which Hughes refers to by using the military term "reverse salient." The AFSCF overcame the technological reverse salient of supporting expanding numbers of satellites in orbit by designing an essentially new system that could handle the increased requirements. Known as the Multiple Satellite Augmentation Program, it turned the AFSCF into a real network for the first time instead of a group of command and control stations loosely bound in a military organization. Within MSAP, problems

occurred requiring solutions, especially equipment interface problems. The Space-Ground Link Subsystem followed MSAP later as the air force tried to expand the capability and reach of the AFSCF. The ground network Colonel Haig built for the weather satellite program reveals in its differences that the AFSCF did not have to evolve the way it did, and in fact shows that other systems could have been developed to challenge the AFSCF. When the air force tried to streamline space operations to make it more like the checklist-driven missile and aircraft communities, institutional momentum diverted this well-meaning goal into further isolating space operations from the rest of the air force operations community. The implications for the future included increasingly incompatible "stove-piped" space systems, while a common-user Air Force Satellite Control Facility stood off to the side.

As the Air Force Satellite Control Facility overcame each reverse salient, it built momentum for future growth that it would later use to keep away customers like the weather satellite and later the Global Positioning System, an unusual choice for a large system. The command and control system did not become autonomous; it acquired momentum, an organizational and technological mass that pushed it along. The momentum of the AFSCF arose from the corporate and military organizations committed to the system. Engineers, managers, owners, investors, civil servants, and politicians all had vested interests in the growth and stability of the AFSCF. Managers overcame technological momentum by introducing a new technology, the Space-Ground Link Subsystem, which made the AFSCF important for every satellite program in the Department of Defense and valuable for some NASA programs as well. At the same time, SGLS helped the AFSCF overcome the momentum building up in the large

numbers of personnel still required to operate the Multiple Satellite Augmentation Program system. SGLS, conceived in 1962, made the AFSCF a common-user network, with the ability to serve every satellite program in development, but the managers chose not to support them all, only "special programs," a euphemism for reconnaissance satellites. Aided by the personnel cutbacks in SGLS, by the end of the 1960s, the air force gave up on the military performing operations and maintenance in the AFSCF, falling back on contractors performing the vital national service of satellite command and control. Finally, just as important as the technological and organizational challenges facing the AFSCF, adapting to its environment required compromises by the manager-entrepreneurs and affected the technological style of the entire satellite command and control system.

The institutional and technological momentum in the AFSCF proved difficult to overcome. The manager-entrepreneurs who ran the AFSCF and the primary customers who justified its existence built the momentum into the system. The Space-Ground Link Subsystem served both parties, advancing satellite command and control technology while enabling the development of even more sophisticated satellites. The special relationship with the NRO continued as the AFSCF supported its patron, by often acting detrimentally to other important national space priorities. Discussion about where the AFSCF fit into the department of defense picture included its unique relationship with the users who existed outside DoD, in particular, the Central Intelligence Agency, and that unusual DoD agency the National Reconnaissance Office.

The major theme that emerges from this study of the evolution of the Air Force Satellite Control Facility is the social construction of technology, in particular the

importance of cultural and political influences on the evolution of large technological systems. This dissertation tries to raise one other significant issue, that of technological systems' momentum, which bureaucrats and program managers often fail to consider. The topic of the autonomous nature of technology raises other questions about the role of human beings in technological systems' development. Obvious from the story is that people designed the technology used for satellite command and control, the machines did not design themselves. It should also be obvious that each major program in satellite command and control came about not because technology evolves organically, but because human beings make decisions to change the technology. If the CORONA reconnaissance system had failed as a detector of Soviet capabilities, or if President Eisenhower had cancelled the program before the extraordinary success of DISCOVERER XIV, there never would have been a Multiple Satellite Augmentation Program, or a Space-Ground Link Subsystem. Each major upgrade to the Air Force Satellite Control Facility significantly increased its usefulness to the national reconnaissance community because of the significant participation of people who continuously refined their techniques of launching ever more sophisticated reconnaissance satellites made the upgrades necessary.

This dissertation also concentrates on the interaction of technology and politics. Because one can define politics to mean the activities or affairs of a government, then the manager-entrepreneurs made political decisions about upgrading the technology, involving a variety of officials at a variety of levels inside and outside the American government and the military. Therefore, AFSCF engineers did not make arbitrary decisions about satellite command and control technology because they wanted to

upgrade or enhance the technology; they made decisions with good reasons in mind. A particularly good example of the role of politics in the evolution of air force satellite command and control is the debate over whether or not uniformed technicians, so-called blue-suiters, should perform operations and maintenance in the AFSCF. In short, the Air Force Satellite Control Facility is as much a political artifact of the space race as it is a technological one.

The model of system formation and growth used to organize this study provides room for the development and coordination of a number of subthemes. These may prove relevant not only to space history but also to the history of technology generally. The subthemes relate in most instances to questions often asked about technological systems and the history of technology in general. For instance, the nature of the air force's role in the National Reconnaissance Program and the role of invention by committee raise questions about the roles of institutions as opposed to individuals in shaping the development of technological systems. Primarily, the air force used its space effort to enhance its traditional mission capabilities, particularly the strategic mission. The air force developed the Air Force Satellite Control Facility as the sole provider of satellite command and control to the military to boost the service's position as the national military space service. Nevertheless, we can never forget that the United States started the CORONA reconnaissance satellite program for one single reason: to crack open the door that kept the nature of the strategic nuclear forces in the USSR a mystery. American leaders believed that by acquiring as much information as possible about Soviet capabilities, they could make the earth a safer place. Nevertheless, the United States Air Force aggressively promoted its role as the military's space force, using the Air Force

Satellite Control Facility to make its case publicly but without ever actually achieving that capability during the 1960s. Again, nothing inevitable emerges about the air force's role in the process.

Another significant issue this dissertation tries to raise is the idea that as they mature, technological systems tend to become less adaptable. As it built momentum, the Air Force Satellite Control Facility prevented other satellite programs from taking advantage of its unique common-user features, driving up the cost of the military space program when those satellite programs, such as the weather satellites and later GPS, had to build their own satellite control networks. By 1969, the United States owned or operated several satellite command and control networks, the AFSCF was merely the largest and busiest. The United States also had NASA's Manned Spaceflight Network, a major contributor to the successes of the Apollo program. The NRO then constructed other satellite command and control networks separate from the AFSCF, which the NRO used to control its own satellites because the AFSCF could not, would not, or the NRO did not want it to. These separate networks included signals-intelligence-gathering ground stations, the most written about being the Alice Springs, Australia, station,[8] a missile warning network, again the most written about being the Woomera, Australia, station,[9] and a weather satellite network, the most important at Offutt AFB, Nebraska.[10]

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[8] See Desmond Ball, *A Base for Debate: The U.S. Satellite Station at Nurrungar* (Sydney: Allen & Unwin, 1987).

[9] See Desmond Ball, *Pine Gap: Australia and the U.S. Geostationary Signals Intelligence Satellite Program* (Sydney: Allen & Unwin, 1988).

[10] See National Reconnaissance Office, *A History of Satellite Reconnaissance, Volume II[Redacted]*, n.d. (Washington, DC: NRO), 203-304, AFSPC/HO.

Unclassified satellite command and control networks include the network of ground stations specifically designed to support only the Global Positioning System (GPS), which the air force operates and maintains. In the 1980s, the air force space systems engineers built the three GPS ground stations at Kwajalein, in the Marshall Islands, Diego Garcia in the Indian Ocean, and Ascension in the South Atlantic, to support the GPS network. These stations cannot support any other satellite programs besides GPS. The air force built this alternate, "stove-piped" tracking network for GPS because the AFSCF could not--or would not--support the twenty-four satellites in the semi-synchronous GPS constellation. In effect, the large amount of momentum in the Air Force Satellite Control Facility exerted a kind of soft determinism on the other space systems under development, forcing them to go elsewhere for support.

Engineers faced difficult challenges when trying to change the direction of a large satellite command and control system--and perhaps that of large sociotechnical systems in general--but such systems are not autonomous. Those who seek to control and direct large technological systems must understand that they are socially constructed artifacts of human culture, not isolated technological systems. Attempts to alter technological systems without taking into account their social, political, and economic environments, among others, may be impossible. If engineers only change the technology, the system may revert to its earlier style, affected more by its environment than any actual technology. Therefore, the environment of large sociotechnical systems must also be attended to as values may need to be changed or institutions altered.

The people who designed the Air Force Satellite Control Facility to command and control space vehicles had one goal in mind when they began: to help win the Cold War.

A higher power motivated them, not a supreme being, but visions of new worlds and ideals of rational order just as important as to the cathedral builders of the Middle Ages.[11] These engineers and managers believed they could win the space race, and they did. They planned to create a safe, new world by providing access to information the American government did not have, particularly about Soviet nuclear capabilities at a time when the USSR lurked vast and unknown behind the Iron Curtain. The goal ultimately became something else entirely different, but just as powerfully motivating--preservation of the command and control network they had built.

A secondary objective of the air force's space effort included the development of space systems, techniques, and the organizational and operational experience necessary to support the traditional air force mission: to fly and fight. Here the air force significantly failed in its developmental goals, never developing anything in space alone, always relying on the expertise and good will of contractors, with the solitary exception of the maverick weather satellite program. The AFSCF has supported the new horizons of Arnold's and von Kármán's vision, but not in a way that helped the service attain much. The air force never built the engineering expertise to build weapons systems on its own and never wanted to, preferring to avoid the arsenal system used by the army. In this period, the air force also failed to develop a cadre of space operators trained in the systems and methods of space operations, able to fly and fight like pilots fly airplanes, instead always relying on contractors not only to design spacecraft but also to operate them. The use of contractors did not--and does not--necessarily constitute a mistake. In

[11] Arnold Pacey, *The Maze of Ingenuity: Ideas and Idealism in the Development of Technology* (Cambridge: MIT Press, 1974), vii.

the 1960s, space played a supporting role on the battlefield, so no compelling need existed--or exists today--to have military people performing these roles and missions. There are no uniformed warfighters in the space business, only warriors who perform missions using space-based assets. Until the day when the United States weaponizes space--the brief flight of an ICBM warhead through the upper reaches of the atmosphere does not truly constitute a space weapon--the air force space mission--as many of its other missions including, for example, airlift--will remain an indispensable supporting mission for the airmen, soldiers, sailors, and marines who actually do the warfighting.

Yet, just as important as the contributions the AFSCF made to the air force in the 1960s, it should be clear that the air force never could act as it wanted with the AFSCF. The AFSCF effectively belonged to and was obliged to the NRO. The air force wanted the satellite command and control mission because it increased budgets and supported the myth that the air force had become the "Aerospace Force," but the AFSCF actually functioned as the NRO's own satellite control range in this period. As the NRO developed increased capabilities into its reconnaissance satellites, the AFSCF had to respond with upgrades to satellite command and control technology, or by adding new tracking stations, one even as recently as 1992 (Diego Garcia), but within its own budgetary means and without other financial support.

As discussions occurred about what the NRO wanted to do with the AFSCF, discussions occurred about what the air force wanted to do with the AFSCF. The air force debated for some time about whether the AFSCF would be an operational unit placed under the authority of a combatant command like Strategic Air Command, or a test and engineering unit, left inside the Air Force Systems Command.. The debates had

as much to do with whether the service could operate satellites like airplanes as they did with budgetary considerations and empire-building. The air force eventually came to the conclusion it could not make operating satellites like flying airplanes because of a lack of airmen in the AFSCF and because many senior military officers simply did not understand the space business. When Gen. James V. Hartinger took over the newly-created Air Force Space Command in 1982, he made a point of educating his staff about space, even to the extent of conducting pop quizzes in staff meetings on mandatory reading assignments, and then posting the scores by name.[12] One senior flying general showed the depth of ignorance about space when he looked at a flat projection of an orbital plot, asking, "How many g's is the satellite pulling at the bottom of the orbit?"[13] Even embarrassing comments like that have not made the air force as aware as "space weenies" would like of the role of space in its day-to-day operations. To some extent, the air force still has not figured out what it wants to do with space.

The Air Force Satellite Control Facility embraced the important myth that the air force could accomplish space operations with an entirely blue-suit workforce. During the 1960s the air force system of satellite command and control did not achieve any important new capabilities for the air service. For two important reasons, blue-suiting never happened: the Cold War and the influence of the NRO. Vietnam siphoned off a large number of air force technical personnel who could have supported the AFSCF by

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[12] James V. Hartinger, *From One Stripe to Four Stars: The Personal Recollections of General James V. Hartinger, USAF, Retired* (Colorado Springs: Phantom Press, 1997), 251-52.

[13] Capt. Tom Carrington, USAF, classroom presentation, Vandenberg AFB, March 1994.

either sending them to fight or reducing their time in the military or inclination to volunteer for military service. Further, the explosion in the aerospace industry in the 1960s drained off even more technical personnel as airmen who might have stayed in the air force longer separated and moved on to other space projects.

In the 1980s, the air force reversed its thinking and tried again to make satellite command and control like flying airplanes. The AFSCF faced another major organizational reverse salient in the creation of Space Command, the air force's next attempt to make space operations as commonplace as flying airplanes and to grab a bigger piece of the space budget. For a short time after the creation of the new space command, the AFSCF remained in the test community of Air Force Systems Command. Eventually, over the objections of many, the air force folded satellite command and control into the operational community, a sign of the increasing importance of the space mission to the air force's institutional vision.

Another point in this story remains the importance of contractors not only to designing air force weapon systems, but also in the space business, operating those weapons systems. The NRO simply preferred to have contractors on console and performing maintenance tasks, perceiving them more experienced, stable, professional, secure, and cost-effective than military personnel. Today this perception still rules, although "out-sourcing" is a relatively recent term. During the early phases of the development of the AFSCF, the hardware and software contractors collaborated to design the systems to air force specifications. The contractors offered suggestions to the service about improving the system, suggestions the air force often accepted because these contractors had previous system design experiences. Later, as the AFSCF gathered

momentum, contractor involvement eroded and an antagonistic relationship between the air force and its former contractor partners gradually developed. General Schriever offers an important warning: the government should not keep operators in the dark as the NRO tried to keep the AFSCF in the dark, or people end up planning for or providing support they should not because they do not understand the real needs, which leads to waste and failed missions. One former contractor said that the best officers he worked with in the late 1950s and early 1960s let the contractors work without micromanaging them, which he attributed to an "operations-oriented, 'can-do'" attitude.[14] Federal workers need to understand once again that it is acceptable for contractors to make a profit when providing a service to the government, so long as they do not fleece the taxpayer. In the words of one former air force space operator, "I cherish the day when the government and contractors were teammates."[15] Finally, compare the costs of doing business today with the costs of doing business in the heyday of the Cold War. The government could not and would not develop an extensive satellite command and control system today as it already has in the AFSCF. The air force's relationship with its contractors needs to go back to the old way of doing business. Given the international environment the United States currently faces, we still need the AFSCF--it is crucial for satellite command and control.

This study has not just been an intellectual exercise in showing the evolution of a large technological system. This work has proven just how important the development of

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[14] Joseph Weitzell, electronic mail to author, SUBJ: "Re: IOS," 22 Nov. 2001.

[15] Rosenberg interview by author.

satellite command and control was to the National Reconnaissance Program and American space programs in general. One may hope that when historians write about the American space program in the future, they will not neglect the satellite command and control system that made those space firsts possible because, in short, no satellite command and control system, no space program. What stays on the ground is at least as worthy of study as what goes in to space.

The author intended this project to meet two goals. First, this project intended to explore the evolution of the military system of satellite command and control using a model of the social construction of a large technological system, proving that the air force developed satellite command and control to support the National Reconnaissance Program. Second, the author wanted to use the history of the Air Force Satellite Control Facility as an example of how to develop an effective space system by understanding the economic, political, and social characteristics that drove its evolution. The reader must decide if this dissertation either found a way or made one.

GLOSSARY OF ACRONYMS

AAF	Army Air Forces
ABMA	Army Ballistic Missile Agency
AFB	Air Force Base
AFBMD	Air Force Ballistic Missile Division
AFHRA	Air Force Historical Research Agency
AFSC	Air Force Systems Command
AFSCF	Air Force Satellite Control Facility
AFSCN	Air Force Satellite Control Network
AFSPC/HO	Air Force Space Command History Office
AMC	Air Materiel Command
ANNE	Annette Island, Alaska, Tracking Station call sign
AOC	Assistant Operations Controller
AP	Advance Projects Facility (a division of Lockheed)
APL	Advanced Projects Laboratory (a division of Johns Hopkins University)
ARDC	Air Research and Development Command
ARPA	Advanced Research Projects Agency
ARS	Advanced Reconnaissance Satellite (also called CORONA, PIED PIPER, or WS-117L)
ARSIC	Advanced Reconnaissance Satellite Intelligence Center
BMD	Ballistic Missile Division
BMEWS	Ballistic Missile Early Warning System
BOSS	New Boston, New Hampshire, Tracking Station call sign
BuAer	U.S. Navy Bureau of Aeronautics
C2	Command and Control
CDC	Control Data Corporation
CIA	Central Intelligence Agency
COMOR	Committee on Overhead Reconnaissance
COOK	Vandenberg (previously Cooke) Air Force Base, California, Tracking Station, call sign
CORONA	Covert name for the reconnaissance satellite program run by the CIA and NRO (also called PIED PIPER or WS-117L)
CSOC	Consolidated Space Operations Center

DARPA	Defense Advanced Research Projects Agency
DCA	Defense Communications Agency
DCI	Director of Central Intelligence
DCS	Deputy Chief of Staff
DDR&E	Director of Defense Research and Engineering
DGS	Diego Garcia Tracking Station, British Indian Ocean Territory
DICE	Satellite Test Center, Sunnyvale Air Force Station, California, call sign
DISCOVERER	Biomedical cover story for the covert reconnaissance satellite program (also called CORONA, PIED PIPER, and WS-117L)
DMSP	Defense Meteorological Satellite Program
DNRO	Director of the National Reconnaissance Office
DoD	Department of Defense
DSCS	Defense Communications Agency Satellite Communications System
DSP	Defense Support Program
DTIC	Defense Technical Information Center
EHF	Extremely High Frequency
ETR	Eastern Test Range
FY	Fiscal Year
GAO	General Accounting Office
GPS	Global Positioning System
GTS	Guam Tracking Station, Guam
GUAM	Guam Tracking Station, Guam, call sign
HTS	Hawaii Tracking Station, Kaena Point, Hawaii
HULA	Hawaii Tracking Station, call sign
ICBM	Intercontinental Ballistic Missile
IGY	International Geophysical Year
IOS	Indian Ocean Tracking Station, Mahe, Seychelles
INDI	Indian Ocean Tracking Station, Mahe, Seychelles, call sign
IRBM	Intermediate Range Ballistic Missile
JCS	Joint Chiefs of Staff
JPL	Jet Propulsion Laboratory
KHz	Kilohertz
KODI	Kodiak, Alaska, Tracking Station, call sign
KTS	Kodiak, Alaska, Tracking Station
MHz	Megahertz
MIDAS	Missile Detection and Alarm System

MOL	Manned Orbiting Laboratory
MOUSE	Minimum Orbital Unmanned Satellite of the Earth
MRBM	Medium Range Ballistic Missile
MSAP	Multiple Satellite Augmentation Program
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NATO	North American Treaty Organization
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NPIC	National Photo Interpretation Center
NRD	National Range Division
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office
NRP	National Reconnaissance Program
NSA	National Security Agency
NSC	National Security Council
OC	Operations Controller
OL	Operating Location
OSD	Office of the Secretary of Defense
PICE	Programmable Integrated Communications Equipment
PIED PIPER	Program name for the Advanced Reconnaissance Satellite (also called ARS, CORONA, and WS-117L)
POGO	Thule Tracking Station, Greenland, call sign
PRELORT	Precision Long Range Tracking Radar
R&D	Research and Development
radar	radio detection and ranging
RAND	Rand Corporation, originally the Research and Development group of Douglas Aircraft Corporation
REEF	Diego Garcia Tracking Station, British Indian Ocean Territory, call sign
RTS	Remote Tracking Station
SAC	Strategic Air Command
SAMOS	name of the former SENTRY satellite program, but not an acronym
SAMSO	Space and Missile Systems Organization
SCF	Satellite Control Facility
SD	Space Division
SE/TD	Systems Engineering and Technical Direction
SGLS	Space-Ground Link Subsystem
SHF	Super High Frequency

SLBM	Sea-Launched Ballistic Missile
SSD	Space Systems Division
STC	Satellite Test Center
STL	Space Technology Laboratories (a division of Philco)
TIROS	Television and Infra-red Observing Satellite
TOO	Technical Operations Order
TRW	Thompson-Ramo-Wooldridge, Inc.
TT&C	Telemetry, Tracking and Control
TTS	Thule Tracking Station, Greenland
UHF	Ultra High Frequency
USAF	United States Air Force
VERLORT	Very Long Range Tracking Radar
VHF	Very High Frequency
WADC	Wright Air Development Center, Ohio
WDD	Western Development Division
WDL	Western Development Laboratories (a division of TRW)
WS	Weapon System
WS-117L	Advanced Reconnaissance Satellite (also called CORONA, PIED PIPER, and WS-117L)
WTR	Western Test Range

APPENDIX A

DRAMATIS PERSONNAE
(In Alphabetical Order)*

Henry Harley "Hap" Arnold (1886-1950) was taught to fly by the Wright Brothers, and commanded the United States Army Air Forces in victory over Germany and Japan in World War II. Before and during World War II, he directed air activities for the nation's global war against Germany and Japan. Under him, the air arm grew from 22,000 officers and men with 3,900 planes to nearly 2,500,000 men and 75,000 aircraft. Early in 1943, Arnold made a 35,000-mile tour of North Africa, Middle East, India, and China, and attended the Casablanca Conference. He suffered a heart attack in 1945 as the war ended, attributed by his doctors to overwork.

Frank S. (Buzz) Buzard (1921-) led CORONA's system integration and operations. His responsibilities included ensuring that all launch, on-orbit, and recovery activities went according to plan, before and after each mission. He got the program back on track when glitches or failures occurred.

Joseph V. Charyk (1920-), the first Director of the National Reconnaissance Office, consolidated the space programs of the Central Intelligence Agency, air force, and navy into one organization. He brought the first American photoreconnaissance satellite, CORONA, into operation and successfully demonstrated signals intelligence technology from space. During his tenure, the NRO operated the U-2 reconnaissance aircraft program and managed development of the SR-71 Blackbird. He left the NRO in 1963 to run the Comsat Corporation, the nation's first telecommunications satellite corporation.

Thomas O. Haig (1921-) worked in the Air Ballistic Missile Division as chief of the requirements office for satellite ground support in the late 1950s, overseeing the design and development of many parts of the tracking stations as well as the control center for CORONA, MIDAS, and SAMOS. He gained a reputation for getting things done, even if it meant cutting through some red tape. The first CORONA photos in August 1960 convinced authorities that prior knowledge of cloud cover over Russia could help photoreconnaissance activities. Because the civilian TIROS weather satellite program

* http://www.nro.gov/corona/pioneers.htm, http://www.af.mil/lib/bio, http://www.peterson.af.mil/hqafspc/history/pioneers.htm, all accessed 26 Oct. 2001; and *World Book Online Americas Edition*, http://www.aolsvc.worldbook.aol.com/wbol/wbpage/na/ar/co/723653, accessed 14 Nov. 2001.

could not yet meet the requirement, the Director, National Reconnaissance Office (DNRO) authorized an interim program. Program II began officially on 1 August 1961. Haig accepted the program director's position on three conditions: that he could use fixed-price, firm-schedule contracts; that he could select the personnel for his program office; and, that he did not have to use a civilian systems engineering and technical direction (SE&TD) contractor. Confronted by problems of operating the meteorological satellites within the ground system designed for CORONA, Haig proposed two dedicated ground stations and a separate control center operated solely by air force personnel with no contractor involvement. Ten months later the nation's first operational satellite program manned entirely by air force military personnel became a reality.

William G. King, Jr. (1918-) initiated the air force Weapon System 117L satellite program at Wright-Patterson AFB, Ohio, in 1955. He successfully advocated the findings of the RAND Corporation reports published in the early 1950s, which argued that space-based systems were technically feasible. Along with some of his fellow officers, he convinced the air force leadership of the value of satellite-based reconnaissance. He led the first competitive acquisition of a military space program. King later served as the Program Director of the air force's SAMOS space program at the Ballistic Missile Division in Los Angeles, California.

Curtis E. LeMay (1906-1990) was the fifth chief of staff of the United States Air Force. The general's second postwar assignment was to the Pentagon as the first deputy chief of the Air Staff for research and development. He built, from the remnants of World War II, an all-jet intercontinental bomber force. He commanded Strategic Air Command for nearly 10 years, laying plans for the development and integration of an intercontinental ballistic missile capability.

Forrest S. McCartney (1931-), one of the first three air force officers to operate a satellite, served at the Satellite Test Center and had responsibility for the on-orbit control of early CORONA satellites. McCartney was at the console during the first successful CORONA mission during DISCOVERER XIV. His military career culminated as Vice Commander of Air Force Space Command and Commander of the Space and Missile Systems Organization.

Brockway McMillan (1915-), NRO Director from 1963 to 1965, vigorously promoted the development of a second generation of reconnaissance satellites, including the ARGON satellite mapping system and the first attempt to acquire higher resolution imagery, the LANYARD program. McMillan also strongly advocated maintaining the NRO as the primary agency in space reconnaissance. He later became chairman of Bell Labs.

Charles L. Murphy (1918-) served as the first CORONA Field Technical Director at the Lockheed Advanced Projects Facility in Palo Alto, where the cameras, the reentry vehicles, and the spacecraft payload came together for testing before shipment to

Vandenberg AFB for launch. He managed the integration, test, launch, and on-orbit operations of the CORONA System.

Frederic C.E. Oder (1919-), beginning in 1956, organized and directed the original Weapon System 117L satellite program at the Western Development Division (WDD). He provided leadership for the development and use of concepts, which fostered the evolution of missile warning, communications, meteorology, and other advanced reconnaissance satellites. His efforts contributed specifically to the success of the MIDAS, SAMOS, and DISCOVERER programs.

Joseph P. (Pat) O'Toole (1923-) was a Control Chief for CORONA operations at the Satellite Test Center at Sunnyvale and supervised the duty controllers. He led operations teams in developing revolutionary procedures to control an on-orbit satellite.

James W. Plummer (1920-), CORONA Program Manager at Lockheed, had overall responsibility for the project. He led the Lockheed team from the early days of WS-117L, through the difficult formative years of CORONA, all the way to CORONA's full operational capability. He later served as Under Secretary of the Air Force and Director of the National Reconnaissance Office.

Thomas S. Power (1905-1970) became commander of the Air Research and Development Command in 1954, a position he held for three years, when he became Vice Commander of Strategic Air Command. When General LeMay left SAC to become vice chief of staff of the air force in 1957, Power became SAC Commander-in-Chief.

Donald L. Putt (1905-1988) became director of Research and Development in the Office of the Deputy Chief of Staff for Materiel at air force headquarters, in September 1948; he became assistant deputy chief of staff for development in April 1951. He transferred to Air Research and Development Command in Baltimore in January 1952 as vice commander until he assumed command on June 30, 1953. Returning to air force headquarters in April 1954, the general became deputy chief of staff for development, and military director of the air force's Scientific Advisory Board.

Simon Ramo (1913-) helped found TRW, an enormously successful defense electronics firm that put together the complex systems required for the first American intercontinental ballistic missile. Ramo-Wooldridge provided technical advice and systems analysis to the Air Force ballistic missile program, which produced the Thor, Alas, and Titan ballistic missiles in a six-year time period.

Osmond J. Ritland (1909-1991), as Vice Commander of the Air Force Ballistic Missile Division and Deputy Chief of the CORONA program, shared, with Richard Bissell, oversight of CORONA, as well as development of the critical three-axis stabilized Agena upper stage that carried the CORONA payload. Bissell and Ritland had originally worked together on the CIA's U-2 reconnaissance aircraft. Ritland's attention to

schedule, without jeopardizing performance, was a major contributor to CORONA's remarkably short development span and prodigious launch schedule.

L. Eugene Root (1910-1992) served as President of Lockheed Missiles and Space Company at the initiation of Lockheed's effort in the air force space programs. An active top executive, he committed the company's total resources to the high priority CORONA program. During the early period of maximum security, he was the only top Lockheed executive briefed on the objectives of the reconnaissance satellite program. He used this responsibility to establish a dedicated facility like the famous Lockheed "Skunk Works," giving the selected team full authority to get the job accomplished.

Robert A. Rosenberg (1934-), from September 1959 until September 1962, served at Vandenberg Air Force Base, Calif., participating in the initial development, test, and launch of Atlas boosters and Agena upper stages. In June 1964, he joined the Office of Special Projects, Office of the Secretary of the Air Force, serving in a variety of positions, including as a mission controller for satellite operations at the Satellite Test Center in Sunnyvale, and later as assistant deputy for test operations at Los Angeles Air Force Station.

Robert M. Salter, Jr. (1920-), a scientist who specializes in elementary particle physics and applied physics, made significant contributions to America's space program, particularly such programs as RAND's *Project Feedback*, PIED PIPER, and CORONA. From 1954 to 1958, Salter worked with the Lockheed Missiles and Space Company as Manager of the Satellite Branch. He also managed the PIED PIPER project (the precursor to the WS-117L program). During that assignment he devised a list of military defense missions attainable by satellites: infrared missile detection; nuclear detonation detection; film recovery; special electronic intelligence; and side lobe radar schemes.

Bernard A. Schriever (1910-) pioneered the nation's intercontinental ballistic missile (ICBM) and served as the first commander of the Western Development Division in Inglewood, California, beginning in 1954. The following year he undertook responsibility for Weapon System 117L, the initial air force space program. He earned the respect early in his career of such influential figures in the air force as Gen. H. H. Arnold, Gen. Thomas D. White, Gen. Curtis E. Lemay, Gen. Donald L. Putt. Simon Ramo, the chief civilian in the ICBM program, believed that another general in Schriever's position "would have had only some of the talents with which Schriever was endowed, and the program[s] simply would not have gone as well."

Hoyt S. Vandenberg (1899-1954), after World War II, ran American intelligence programs. He returned to duty with the Army Air Forces in April 1947, and in April 1948, became the second Chief of Staff of the Air Force.

Theodore von Kármán (1881-1963) became one of the outstanding scientists of the twentieth century. His primary interest was aeronautics, but he wrote nearly 150 books

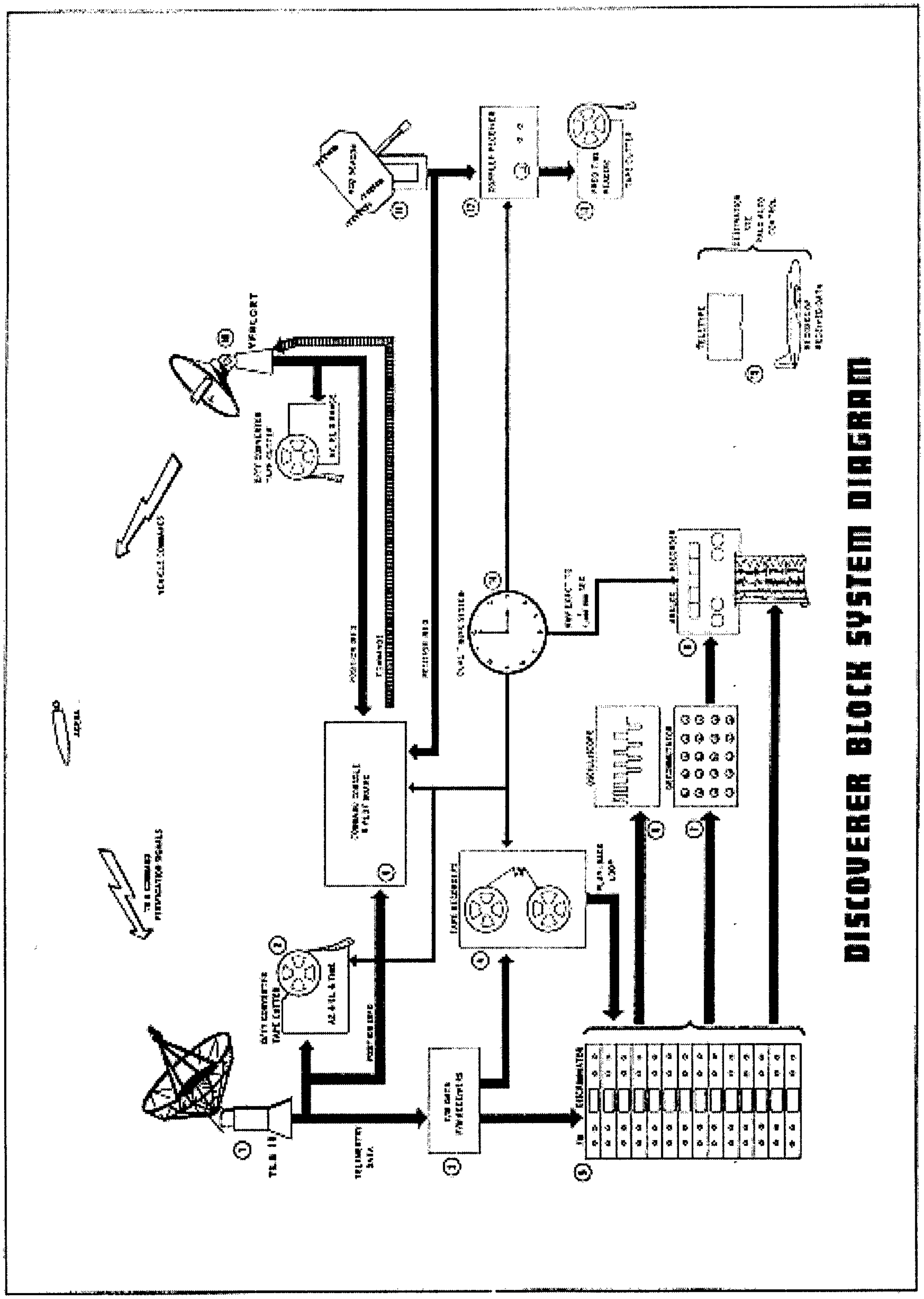
and articles on many aspects of engineering, physics, and mathematics. Von Kármán helped found important aeronautical institutions and agencies, including the Guggenheim and Jet Propulsion Laboratories at the California Institute of Technology and the Air Force Scientific Advisory Board.

Thomas D. White (1902-1965) transferred to the Office of the Secretary of the Air Force in October 1948, becoming director of Legislation and Liaison. He was appointed, in May 1950, air force member of the Joint Strategic Survey Committee in the Office of the Joint Chiefs of Staff. He was assigned as director of Plans, Headquarters Air Force, in February 1951, and in July 1951, assumed duties of deputy chief of staff of operations for the Air Force. White became the fourth Chief of Staff of the Air Force on July 1, 1957.

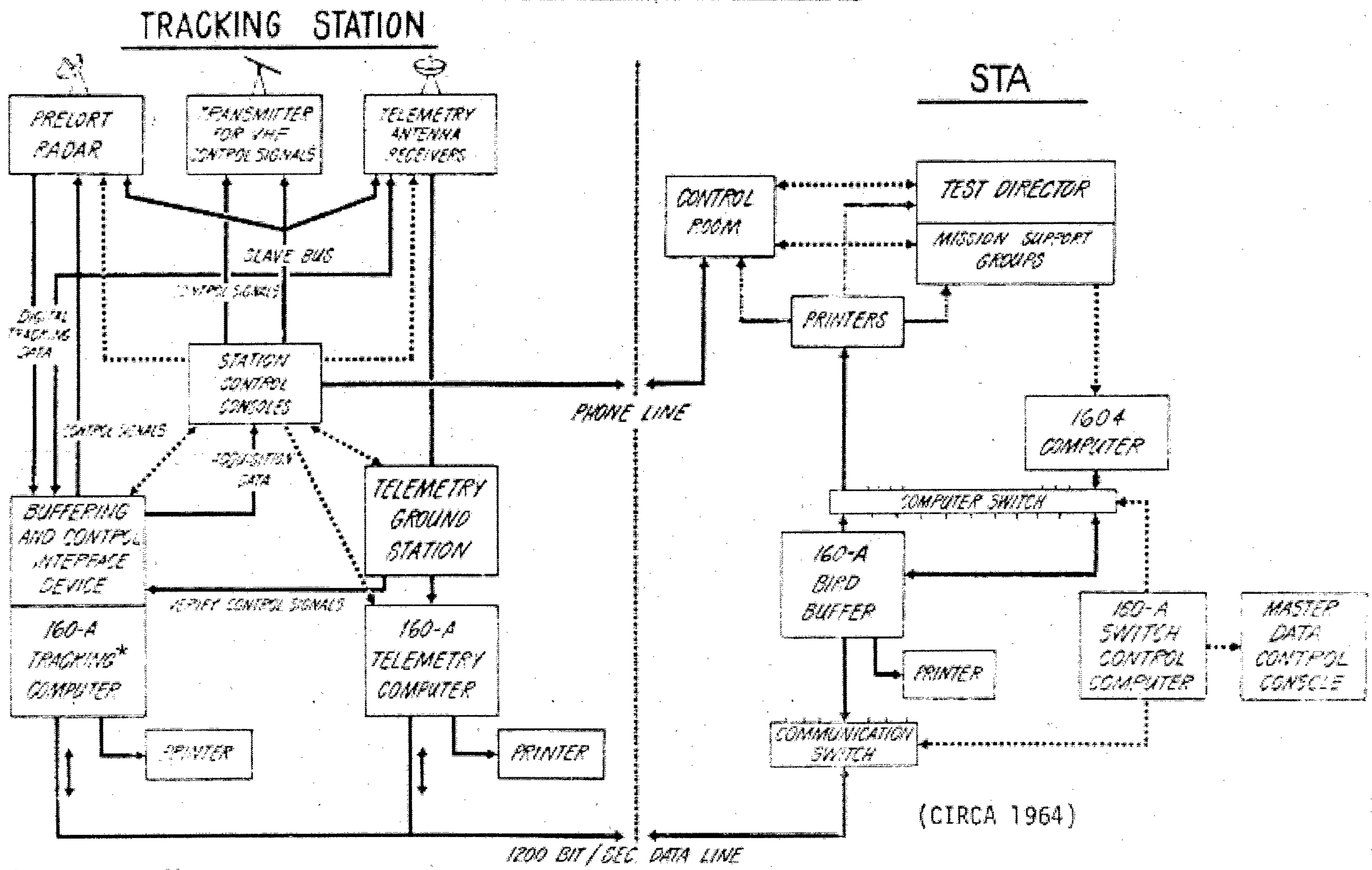
APPENDIX B

REMOTE TRACKING STATION FACILITIES DESCRIPTIONS*

* Jernigan, *Air Force Satellite Control Facility: Historical Brief and Chronology.*


DISCOVERER BLOCK SYSTEM DIAGRAM

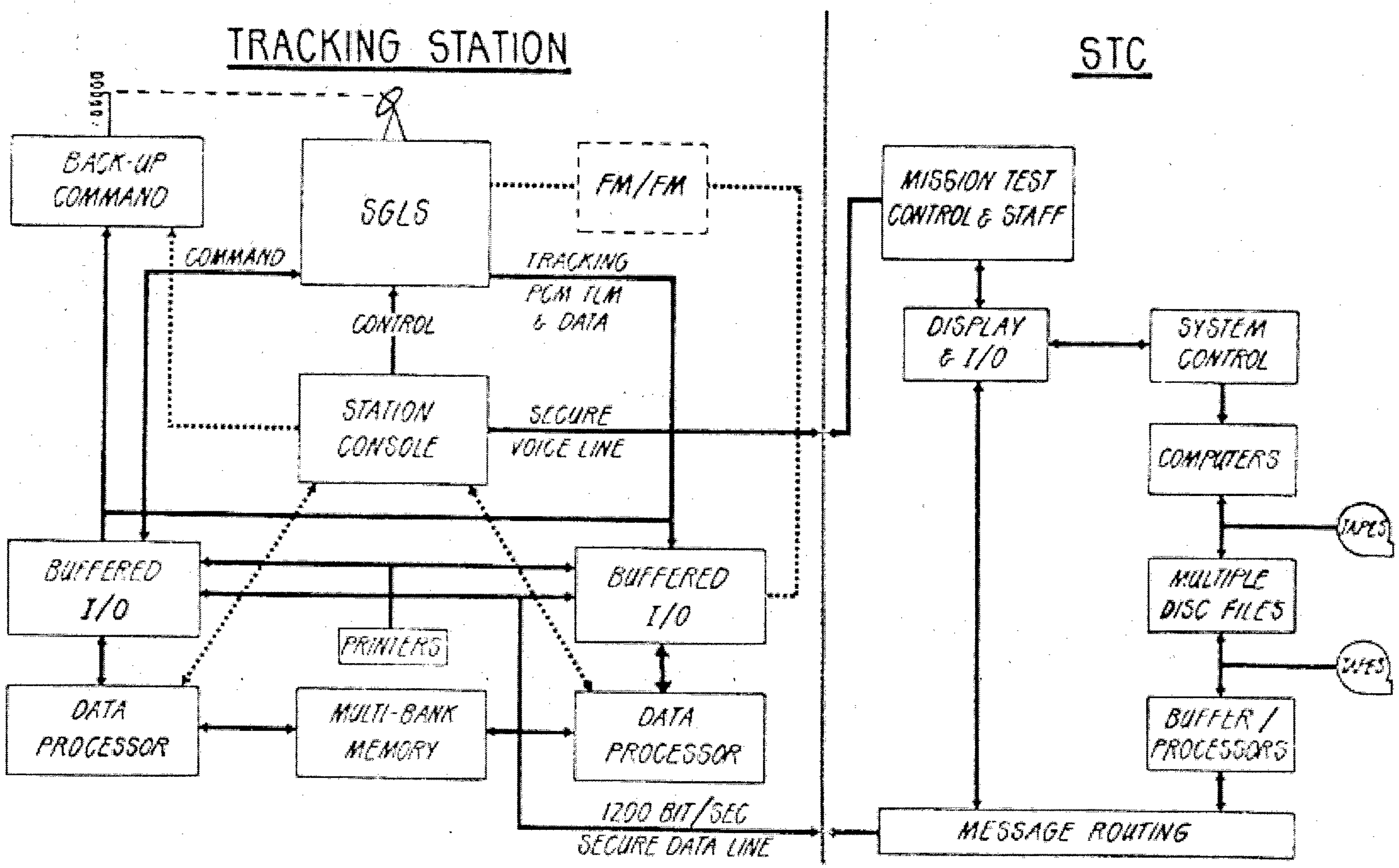
SYSTEM DESIGN (OVERALL DATA FLOW CONCEPT)



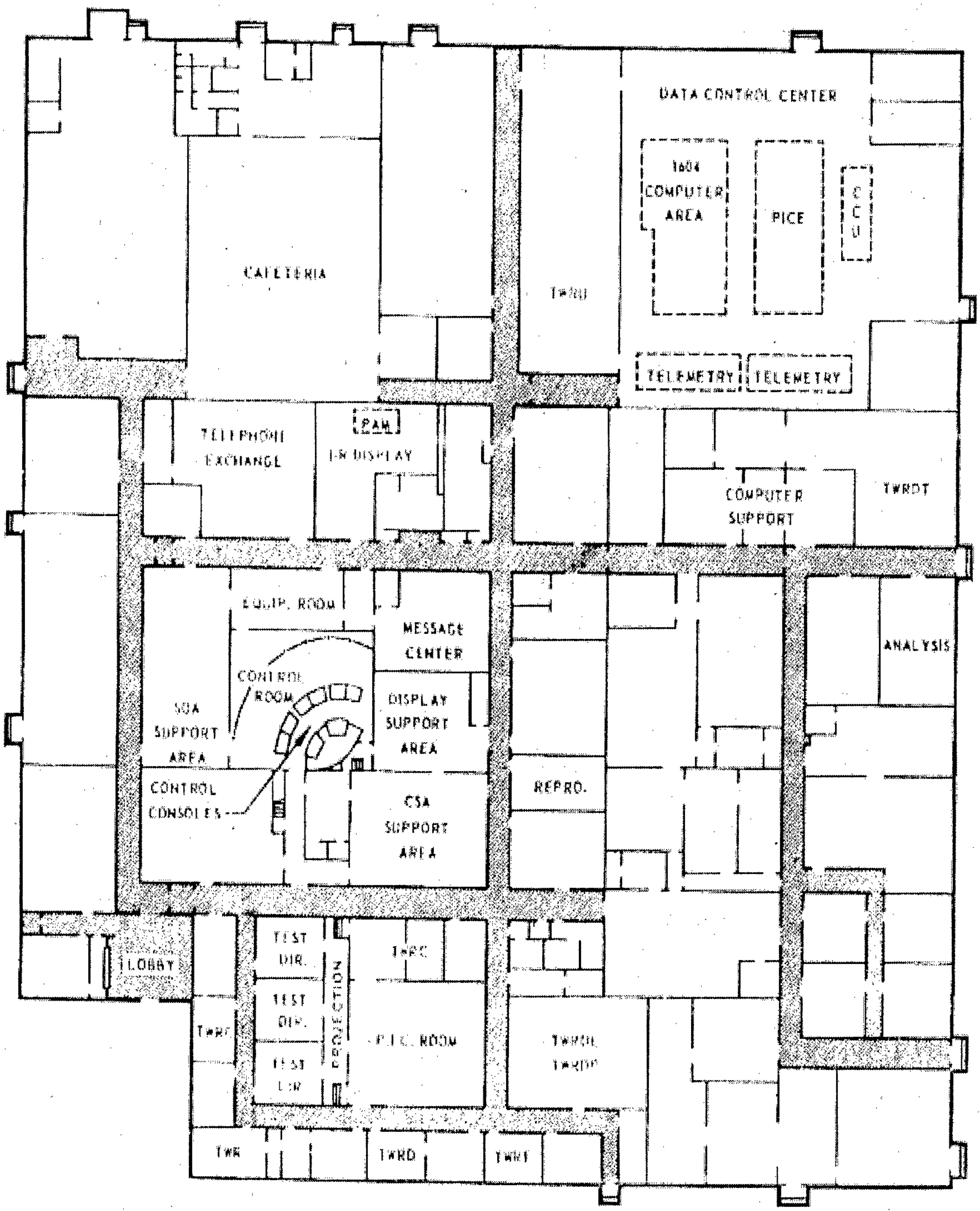
(CIRCA 1964)

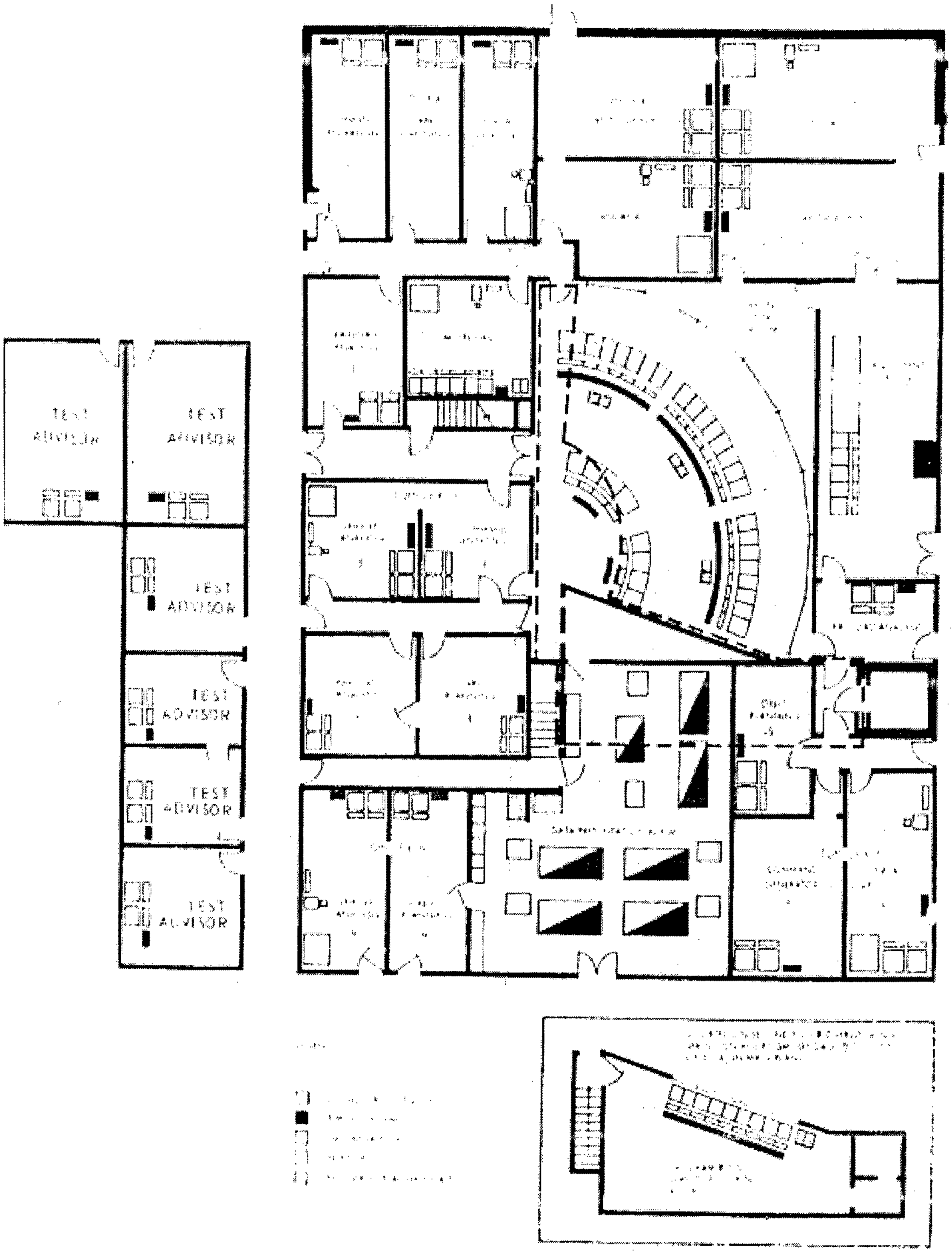
*and commanding

SYSTEM DESIGN 1967-70



STC LAYOUT - 1961





1964 - STC CONTROL AREA

APPENDIX C

GENERAL CHRONOLOGY OF THE AIR FORCE SATELLITE CONTROL FACILITY*

1947	RAND Study indicated the feasibility of a satellite for reconnaissance
1 July 1954	General Schriever established Western Development Division (WDD)
March 1955	General Operations Requirement #80 published stating need for satellites
15 Feb. 1956	WS-117L responsibility transferred to WDD from Wright-Patterson
29 Oct. 1956	Lockheed Aircraft Corp awarded the contract to develop and test WS-117L
1 June 1957	WDD redesignated Air Force Ballistic Missile Division (AFBMD)
4 Oct. 1957	SPUTNIK orbited
22 Jan. 1958	National Security Council gave WS-117L highest national priority
31 Jan. 1958	EXPLORER I, USA's first satellite, orbited
19 March 1958	WS-117L reoriented to include a recoverable package, instead of readout
30 June 1958	ARPA assumed development responsibility for military space programs
15 Aug. 1958	AFBMD Field Test Force established in Palo Alto, CA
15 Sept. 1958	AFBMD issued "New Horizons" development plan
1 Oct. 1958	National Aeronautics and Space Administration (NASA) established
Jan. 1959	Interim Satellite Control Center completed in Palo Alto, CA
4 Jan. 1959	Vandenberg Tracking Station declared operational
28 Feb. 1959	DISCOVERER I launched (mission failed)
2 April 1959	6594th Test Wing organized at Palo Alto, CA
25 April 1959	General Schriever promoted to Lt. Gen. and became ARDC Commander
1 July 1959	Vandenberg Tracking Station designated 6594th Instrumentation Squadron
Feb. 1960	First ATLAS booster test fired at Vandenberg AFB
1 March 1960	6594 Test Wing (Satellite) moved to Sunnyvale control complex
1 May 1960	Francis Gary Powers' U-2 shot down over the USSR

* "Advanced Reconnaissance System Weapon System 117L," 10 Feb 1959, NRO 1/B/0045; Peebles, *Corona*, Appendix 1, 271-315; Jernigan, *Air Force Satellite Control Facility Historical Brief and Chronology.*

14 June 1960	Aerospace Corporation incorporated
10 Aug. 1960	DISCOVERER XIII orbited
11 Aug. 1960	DISCOVERER XIII water recovery
18 Aug. 1960	DISCOVERER XIV orbited
19 Aug. 1960	DISCOVERER XIV aerial recovery
31 Aug. 1960	Air Force Office of Missile and Satellite Systems created under SecAF
23 Sept. 1960	Air Force assigned responsibility for military space programs, not ARPA
1 April 1961	Air Force Systems Command formed from parts of ARDC and AMC
1 April 1961	VTS became all blue-suit when USAF assumed responsibility for sat C2
25 May 1961	President Kennedy called for effort to reach the moon by end of the decade
3 Oct. 1961	Satellite Test Annex assumed sole responsibility for satellite C2 operations
1 Nov. 1961	6594 Test Wing (Sat) redesignated 6594 Aerospace Test Wing (Satellite)
June 1962	STA upgraded for Multiple Satellite Augmentation Program (MSAP)
Dec. 1962	STA operated 5 satellites simultaneously
28 Sept. 1963	Indian Ocean Station operational just six months after equipment arrived
18 Nov. 1963	VTS loses all 70 Philco employees as MSAP equipment is installed
Dec. 1963	First MSAP supports
2 Jan. 1964	AFSC established the National Range Division at Patrick AFB, Fla.
27 March 1964	Great Alaskan earthquake destroyed the road to Kodiak Tracking Station
27 March 1964	National Reconnaissance Office chartered
June 1964	6594 ATW published Manual 375-1, standardizing operations procedures
13 Oct. 1964	NHS achieved full dual-support capability under MSAP for the first time
1 July 1965	Air Force Satellite Control Facility organized with HQ at Los Angeles
July 1966	GAO said use of blue-suit and contractor O&M personnel was illegal
Aug. 1966	VTS declared fully SGLS-capable
27 Jan. 1967	Astronauts Grissom-White-Chaffee killed in AS-204 (Apollo I) fire
31 Dec. 1967	National Range Division disestablished
25 May 1972	Last CORONA mission launched, Flight #145
31 May 1972	Last CORONA recovered

BIBLIOGRAPHIC ESSAY

In August 2000, my house became a satellite tracking station. Sears sold an eighteen-inch satellite dish in a box, and a subcontractor (of course) stuck it up on the side of the house. Then, to paraphrase Bruce Springsteen, the television had 157 channels and nothing on. That eighteen-inch dish turned the house, for less than $200, into a passive tracking station for a geostationary communications satellite, while each remote tracking station in the Air Force Satellite Control Facility cost the American taxpayer millions (although they certainly had many more capabilities and sophistication than my small dish). The new eighteen-inch system could do nothing more than receive, but it was capable of something that even nation-states could not accomplish two generations ago. The transformation that has occurred in two generations deserves study.

Two books that are contemporary with the initial development of satellite command and control are Shirley Thomas's *Satellite Tracking Facilities* and Eloise Engle and Kenneth Drummond's *Sky Rangers*.[1] The author rescued these books from certain oblivion in the discard piles of local libraries, one in Farmington, Utah, and another in Columbus, Georgia. When these books were published in the early 1960s, space was new and exciting and anything associated with it probably launched off bookshelves.

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[1] Shirley Thomas, *Satellite Tracking Facilities: Their History and Operation* (New York: Holt, Reinehart and Winston, 1963); and Eloise Engle and Kenneth Drummond, *Sky Rangers: Satellite Tracking Around the World* (New York: The John Day Company, 1965).

These two books, however, are little more than surveys of the various technologies available at the time to track satellites, superficially covering a wide variety of topics from NASA's Minitrack network to the navy's space surveillance network. Because at the time "to track" a satellite meant command and control as much as it meant watching an object cross the sky, these two books are just as devoted to radio tracking as they are to visual observation of satellites. They are the last books exclusively devoted to satellite tracking until the twenty-first century.

NASA official histories have had little to say about the ground networks that made it possible for controllers to be in touch with astronauts or to monitor their own satellite programs. The official history of the Vanguard program,[2] the nation's first civilian satellite project, talks about its network of tracking stations, Minitrack, in some detail. Because Minitrack was a network planned for one satellite program, it accomplished very little after "Kaputnik," a nickname for the 6 December 1957 failure of the Naval Research Laboratory's first attempt to leave the launch pad. Minitrack's long-term significance rests in its inclusion into NASA's many and varied manned and unmanned programs. In the official history of the piloted Mercury program, *This New Ocean*, there is some discussion of the tracking network, but mostly as it relates to the obsession of flight surgeons for constant contact with the astronauts during all phases of spaceflight. But according to the authors, the full extent of the tracking range and communications network was beyond the scope of their 681-page volume.[3] By the time

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[2] Green and Lomask, *Vanguard: A History.*

[3] Swenson, et al., *This New Ocean*, pp. 214-15.

one finally reaches the Gemini and Apollo programs, other technologies and factors play such an important role that the ground segment of these programs, largely built for Mercury and kept on into Gemini and Apollo, blend into the background.

Douglas Mudgway's history of NASA's own satellite command and control network, called the Deep Space Network, corrected some of the omissions of previous NASA histories. *Uplink/Downlink*, however, is an internalist history of a technology, doing little to enhance our understanding of the social construction of large technological systems. A typical "nuts and bolts" look at the way NASA developed its satellite command and control methods, in fact, continues the myth that the history of technology is about artifacts, not about the people who created them.[4]

An official NASA publication that does not ignore the history and development of NASA's ground network is James R. Hansen's story of the Langley Research Center,

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[4] Douglas J. Mudgway, *Uplink/Downlink: A History of the Deep Space Network*, NASA SP-2002-4225 (Washington, DC: Government Printing Office, 2002). Also needed, though, is a history of the ARIA aircraft, which were essentially flying tracking stations that NASA first used for the Apollo program, but which the air force recently retired because of cost (upwards of $100,000 an hour to fly), replacing them with the NKC-135B Big Crow. ARIA was an acronym for Apollo Range Instrumentation Aircraft, developed in 1968 to receive, record, and retransmit telemetry data and voice communications between astronauts and the Houston Control Center. Later known as the Advanced Range Instrumentation Aircraft, the ARIA fleet consisted of eight highly modified EC-135 and EC-18B/D aircraft maintained by the Air Force Material Command's 452d Flight Test Squadron. ARIA aircraft served as airborne tracking stations often over water when ground tracking stations were out of range of a satellite's mission profile. A recent success came in 1996 when NASA used an ARIA aircraft to help the Mars Global Surveyor reach its planned trajectory by sending data through an antenna at the Diego Garcia Tracking Station, into the Air Force Satellite Control Network data stream, and out to NASA's Goddard Space Flight Center. http://www.edwards.af.mil/aria, accessed 11 Jan. 2000; Leigh Anne Bierstine, "ARIA makes final touchdown at Edwards," 27 Aug. 2001, http://www.af.mil/news/Aug2001/n20010827_1185.shtml, accessed 27 Aug. 2001.

Spaceflight Revolution.[5] Hansen nicely fits the development of the tracking station networks into Langley's (and NASA's) overall story. This work includes anecdotes about survey trips, including a story about a team that set down in the Congo in 1966 to do a survey for a Mercury tracking station, and found themselves in the middle of the first Congolese Revolution.

Official United States Air Force publications, of which there are many volumes of organizational history, say even less about satellite command and control. In fact, nothing, save three pages in David N. Spires's official air force in space history, *Beyond Horizons*, has been written about the men and women on the ground and the equipment that they used to make the space programs of the United States possible.[6] Their contributions have remained in the background, until now, even though the Air Force Satellite Control Facility was and is an indispensable and dynamic organization that underwent many evolutionary changes on its way to becoming the first common-user network for space command and control.

Although there is a wide variety of information available on satellite command and control, it is often hard to find because archivists have buried it in other topical collections. Further, the documents that deal with satellite command and control also deal with a variety of other details regarding myriad satellite programs. Once the Air Force Satellite Control Facility became an independent organization and began recording

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[5] James R. Hansen, *Spaceflight Revolution: NASA Langley Research Center from Sputnik to Apollo*, NASA SP-4308 (Washington, DC: Government Printing Office, 1995), p. 67.

[6] Spires, *Beyond Horizons*, pp. 167-169.

its own official histories, more administrative details became available but even fewer technological details.

In the hope of sparing future researchers the frustrations of dead ends and false starts, this essay contains information not usually found in bibliographies. Where applicable, I have included either the depository where the documents can be found or the other details necessary for tracking them down. Already having a defense department security clearance because of my status as an air force officer on active duty speeded up the process for requesting declassification review, but rest assured, the documents are there, waiting for civilian historians to mine them.

The largest collection of documents on the administrative history of the Air Force Satellite Control Facility lies in a vault near Colorado Springs, at the Air Force Space Command Headquarters History Office (AFSPC/HO) on Peterson Air Force Base. AFSPC/HO's historians, while overworked, understaffed, and with a critical shortage of office space, took valuable time to help me find what I needed. There are boxes and boxes and reams and reams of official documents and photographs on the history of the Air Force Satellite Control Facility, most of which unfortunately--and unnecessarily--remain classified. The nature of the collection is such that it is unique and literally unduplicated anywhere in the air force. Researchers should beware that special arrangements need to be made for viewing and using the collection because of its classified status, the nature of the history office as a functioning official military unit, and the complete lack of space for researchers in the history offices.

An equally valuable repository that is set up to handle researchers is the Air Force Historical Research Agency (AFHRA) at Maxwell Air Force Base, in Montgomery, Alabama. AFHRA's sole mission is to help researchers in and out of the air force write history. The collection is open to the public and the archivists bend over backwards to help, pleased to have people look at their collections. Their collections run the gamut from oral histories and official histories to special studies, technical documents, and personal papers.

An equally valuable collection, but still difficult to use, is the National Reconnaissance Office (NRO) in Chantilly, Virginia. Their collection of declassified and redacted documents from the previously classified CORONA, ARGON, and LANYARD satellite programs is helpful, but focuses almost entirely on the development of the satellites themselves, not the system of command and control that made them useful for national security. Further, NRO's obsession with security requires advance planning for the researcher and the understanding that a lot of details are available elsewhere but redacted here.

The hardest nut to crack was the Defense Technical Information Center (DTIC), a repository of every technical report written under defense department contract and a great source of developmental details on satellite command and control, but closed for most significant details to most non-defense department users. Many documents in DTIC's collection on the CORONA satellite program's Subsystem H remain unnecessarily classified. Although searchable on-line, DTIC does not have a reading room and is set up to support the needs of the defense community, not historical researchers. If you are

interested in exploring the technology of satellite command and control in much greater detail, including down to the box level, or if you enjoy wiring diagrams and organizational charts, then this is definitely a place you must visit on-line at http://www.dtic.mil.

By far the most valuable resource for this dissertation has been the personal insights of the people who were there when it all happened. Until the declassification of the CORONA program in the 1990s, many of the pioneers of the American military's space program *could* not and *did* not talk about their experiences. Because of this, many of the recorded official histories do not contain references to the early satellite programs. In addition, many of these people could not write anything down during their tenures and so much of the evidence remains oral history, sometimes tainted by fading memories and personal embellishments. Historians do not often have the opportunity to talk to the original participants, but historians of space history and other recent history topics, certainly should not pass up this opportunity to meet the pioneers of their field of research. The author has been privileged and honored to meet some of them and to talk with others on the telephone. In addition, using electronic mail the author has met and talked with others who have provided incredible details that were not written down anywhere until now.

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